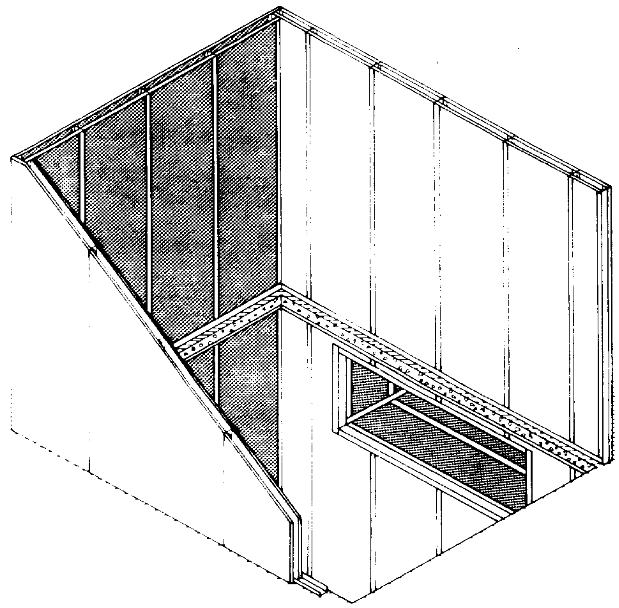
Gypsum Board and HVAC



The Concept Isn't New—But Gypsum Board Should be Considered for Use in HVAC Systems

By George E. Meyer and Billy Brittain

A frequently discussed issue among commercial building designers and architects concerns materials for air ducts, shafts, and plenums. Gypsum board systems are commonly used to provide fire resistance protection for separate air ducts constructed from other materials. For large commercial projects, and where permitted by applicable codes, many designers have reduced construction costs by utilizing the fire protection gypsum board systems as the lining for the HVAC systems.

The purposes of this article are:

(1) to examine some of the features and potential problems of this cost-saving technique,

(2) to define those applications where the use of gypsum board systems should be considered, and

(3) to enlighten and encourage responsible officials and designers to accept limited use of gypsum board liners for HVAC systems in areas where building codes do not currently permit its use.

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Introduction

Gypsum board and light gauge steel framing fire protection assemblies has evolved into the enviable position of setting new standards for reducing total construction costs of high-rise buildings. Many of today's tallest buildings may not have been economically justified without their development. Gypsum board is one of the lowest cost construction materials available and can be erected with proper precautions in most weather conditions by an available skilled work force. Its light weight and convenient panel sizes save construction costs in many ways.

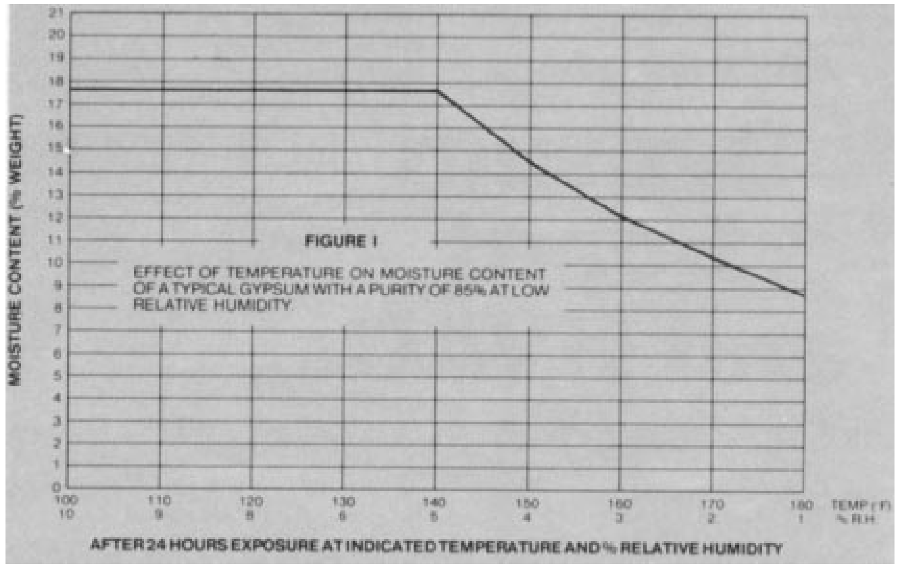
Some local and model building code groups have approved specific gypsum board assemblies for use as liners in HVAC systems, with some limitations. Other codes refuse to permit this use under any condition. The latter category is based on the premise that gypsum board does not meet the requirements of NFPA 90A[1], to which their codes subscribe.

NFPA 90A dates back to 1899 with periodic revisions (most recently in 1981) to update the standard. The commercial development and use of gypsum board for walls and ceilings dates back to the 1920s, with major expansion of available systems and use during the 1950s. Revisions to NFPA 90A to include the limited use of gypsum board as liners for HVAC systems are appropriate and may eliminate the need to appeal this issue at the various building code levels.

Discussion

Room air can be heated, cooled, humidified or de-humidified, depending on the ambient conditions desired in the occupancy area. These operations might cause temperature and moisture content changes to the liner of an air supply HVAC system, affecting its ability to withstand corrosion and induced stresses. With the exception of induced stresses, the lining of return HVAC systems are not exposed to conditions more severe than the occupancy area. The following sections discuss thermal effects, moisture effects, fire hazard effects, building code activities and structural considerations for the use of gypsum board as liners for HVAC systems.

KEY WORDS: calcination; controls; dew point; diseases; duct; fire resistance; frame spread; gypsum board; heating; ventilating, and air conditioning (HVAC); high-rise buildings; humidity; moisture; plenum; shat; smoke developed; structural; temperature; thermal; water.



1. Thermal Effects. The strength properties of gypsum board are derived in part from the crystalline structure of the gypsum core.[2] These crystals contain nearly 50% chemically combined water by volume which results in effective resistance to fire. On exposure to a high temperature heat source, the temperature of gypsum board slowly increases, then stabilizes near the boiling point of water until most of the chemically combined water is driven off as steam, a process known as calcination. At the same time, the crystalline structure of the gypsum core changes into a different, more dense structure with lower intercrystalline or gypsum core strength. Type 'X' gypsum boards usually contain additives to improve this calcined strength, enabling it to remain in place as a barrier to fire for a longer period of time. Other additives in some Type 'X' gypsum boards decrease thermal transmission through the calcined gypsum core. Gypsum board, depending on ambient air humidity, either gains or loses free water when continuously exposed to 140°F, and may be stable to occasional short exposures at much higher temperatures. (Refer to figure 1.)

Air heating operations not properly designed for gypsum board liners in HVAC systems could produce temperatures high enough to start calcination, thereby reducing the fire resistance protection provided by the gypsum as well as impairing structural properties. Calcination would usually be restricted to the vicinity of the heat exchanger and be easily detected as a discoloration or delamination of the surface paper. Where controls are utilized to insure that surface liner temperatures do not exceed 125 °F, gypsum board has performed satisfactorily. Gypsum board may also be protected by using supplementary heat-resistant linings in the immediate vicinity of high-temperature heating elements.

2. Moisture Effects. Moisture accumulated either by overspray, condensation, or induction from added humidity causes other problems in HVAC systems constructed from any material. Moisture may accumulate either within localized areas or throughout an entire air supply HVAC system if the surface liner temperature is lower than air stream dew point temperature. Energy losses and corrosion problems are tangible examples of the effects of condensation.

Condensation conditions also foster growth of micro-organisms suspected of causing disease[3,4,5,6] through airborne transmission. Designers and operating engineers of HVAC systems should exercise caution to avoid condensation and its related problems regardless of liner materials used for construction.

When moistened, gypsum board loses part of its structural integrity, but will recover after drying. Moisture-resistant surface papers and/or gypsum cores extend protection to intermittent water exposure, but do not provide permanent protection from continuous condensation or overspray. Moistened gypsum board can be detected by a softer and sometimes discolored gypsum core. In extreme cases, the surfacing paper may delaminate from the gypsum core.

Where controls are utilized to insure that air stream dew point temperatures do not exceed surface liner temperatures, gypsum board liners for HVAC systems are performed satisfactorily.

3. Fire Hazard Effects. Gypsum board products have a paper surface. When tested in accordance with ASTM E-84[7], they develop a *flame-spreading rating* of 10-15 and a *smoke-developed rating* of 0. This is considerably better than some material permitted with a class 1 rating by codes for limited applications that may have a flame spread rating of up to 25 and a smoke developed rating of up to 50.

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Gypsum board has a long history of use in the walls and ceilings of fire rated constructions. The very low flame spread, smoke and fuel contribution of gypsum board provide fire rated protection to adjoining areas. For critical specific classes of occupancy and types of construction, current codes require fire and smoke dampers at entry and exits to air ducts and/or plenums. These devices are designed to prevent flame from entering the HVAC system and to prevent draft through the system during a fire. In the event a sustained fire from an external source enters an HVAC system, the surface properties of the lining would be irrelevant if it contributes no fuel to feed and spread the fire.

4. Building Code Activities. As early as 1964, ICBO Research Recommendation 1874.1 approved gypsum board for the lining of duct and plenum chambers of automatically operated systems where the interior temperature would not exceed 125 °F, and other approved materials were used within six feet of the furnace or heat exchanger casing. Use of gypsum board is allowed by the current ICBO Mechanical Code[8], reading as follows:

Where gypsum products are exposed in ducts or plenums, the air temperatures shall be restricted to range from 50°F to 125°F and moisture content shall be controlled so that the material is not adversely affected. Gypsum products shall not be exposed in ducts service evaporative coolers.

Many designers have used vertical gypsum air shafts to reduce building costs and particularly to utilize horizontal plenum areas of floor-ceiling assemblies. But the use of plenum areas in fire-rated floor-ceiling assemblies for HVAC systems may be difficult and expensive to design and install.

In areas under the jurisdiction of other codes, the use of gypsum board as an air shaft may not be specifically covered, or it may be limited for use in buildings not to exceed two stories in height. Such codes usually subscribe to the provision of NFPA 90A.

The practice of some architects and builders is to seek a variance to local building codes for the purpose of permitting gypsum board as a plenum or shaft material on individual specific buildings. These variances may sometimes be granted on the basis of some innovative technical feature incorporated in the building design or on interpretations of intent and meanings of the codes. Hearings for these purposes are time consuming, repetitive and costly for both architects and building departments.

NFPA 90A is a design installation standard for general duct system use based on materials explicitly approved. Approved materials include iron, steel, aluminum, concrete, masonry, clay, or asbestos cement. In addition, NFPA 90A permits the use of other materials meeting Class 0 or Class 1 performance test requirements of UL 181[9], provided they:

(1) may be used as ducts for vertical risers serving more than two stories,

(2) shall be installed in accordance with the condition of their approval, and

(3) shall not be used in air duct systems which operate with air entering the ducts at a temperature higher than 250 °F.

Certain treated wood and plastic products might meet Class 1 requirements of UL 181, but gypsum board products are effectively excluded. No conventional gypsum board product will meet the resistance to deterioration requirements in UL 181 after exposure to high temperature (60 days at 265°F). There are additional requirements in UL 181 under severe humidity and moisture conditions which gypsum products would also not meet.

As an example of confusion in interpretation, some local codes state gypsum shafts "are not to be used as vertical risers for air ducts serving more than two stories." Even though the intent of this statement is probably identical with the limited use exception in NFPA 90A, the meanings could be interpreted differently. Gypsum shafts are usually constructed between floors of high-rise buildings and are structurally independent of similar shafts on other floors. The air moved within the shafts, however, usually serves several or sometimes all floor levels.

As an additional limitation, NFPA 90A specifies "a fire resistive enclosure used as a vertical duct more than two stories in height shall be constructed of masonry, concrete, or clay tile." This excludes gypsum board as well as metals. It also fails to address the development of structurally independent ducts on each floor level.

NFPA 90A specifies that plenums meet all requirements for ducts or alternatively conform to other specified requirements. In these alternate sections, combustible materials are not permitted in the concealed space nor are they permitted as part of the ceiling construction. The problem concerns the definition of "combustible," which is not included in NFPA 90A. Certain construction materials with a flame spread rating of not over 25 and a smoke developed rating of not over 50 would be permitted as a ceiling material of a plenum. However, such materials may have "limited" combustibility.

5. Structural Considerations. Structural design load-deflection properties of all duct materials tested to UL 181 are based on specimens of limited size with limited spacings of joints, fasteners and supports. This date does not provide sufficient design information for static pressure uniform loading conditions of large air distribution systems that also serve as a wall partition or ceiling membrane. The ability of any approved duct material or system to sustain static uniform design pressures during exposure to fire for any fire resistance rated period has not been investigated. A test procedure to evaluate these properties may not currently be feasible.

Many designers have applied load-deflection characteristics of gypsum board wall systems derived from ASTM E-72[10] tests to the designs of linings for HVAC systems. This procedure utilizes a test partition which is unrestrained along both edges. Data is independent of corner reinforcement and load-deflection criteria can theoretically be applied to an infinite width partition. Such load-deflection data are usually summarized in tabular form listing the height limits of partitions to meet various deflection limits under various design loads, usually expressed in pounds per square foot. UL 181 does not provide a method to measure deflection of planar membrane sections under various design pressure loads, probably due to a lack of need for such data with currently approved materials, properly concealed by a gypsum board fire protection system.

Caution should be taken with the type and spacing of perimeter fasteners used with gypsum board and light gauge steel framing systems. Manufacturers' literature and fire test reports indicate perimeter fasteners are to be spaced a minimum of 24 inches on center. In some applications, 24-inch spacing of fasteners would be inadequate to sustain the design loads. Comprehensive design data on this subject may be found in AWCI Steel Framing Systems Manual, pages 15 and 16.[11]

Overview

Where automatic control systems have been used to avoid overheating and/or moisture condensation, liners for HVAC systems constructed of fire-resistance rated gypsum board systems have performed satisfactorily and reduced overall construction costs.

The return air portion of an HVAC system does not handle high temperature or high humidity air which could cause problems with gypsum board liners. Returned air does not expose the HVAC system liner to any greater heat and moisture than would exist in the occupancy area the HVAC system serves.

Modification of model, state and city building codes should be encouraged to permit use of gypsum board linings in HVAC systems of high-rise buildings, subject to the following limitations:

(1) Thermostatic controls shall be used to insure gypsum board surface

temperatures are not sustained above 125 °F.

(2) Humidity controls shall be used to insure air stream dew point temperatures are maintained below gypsum board surface temperatures.

(3) Separate approved liners shall be installed in areas with continuous exposure to overspray, condensation or air stream temperatures exceeding 125°F.

(4) The gypsum board system shall be constructed to withstand sustained design uniform pressure loads without structural failure and, in addition, shall comply with deflection limits regulated by building codes at the design uniform load, if also used as a wall or ceiling.

When standards or codes require the use of a specific material or method, the development of lower cost materials or methods for this use is essentially eliminated. Perhaps NFPA 90A should be reviewed with the objective of replacing those sections concerning *approved materials* with *performance requirements.* In addition, terminology needs to be expanded and clarified, recognizing requirements for air supply liners are different from those for air return liners in HVAC systems.

Performance requirements should be evaluated by a test procedure(s) under the control of a voluntary standards consensus group (such as NFPA or ASTM) with balanced voluntary input by consumers, producers and general interest members. Reference to a proprietary test procedure, such as UL 181, may not represent all segments of the industry.

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