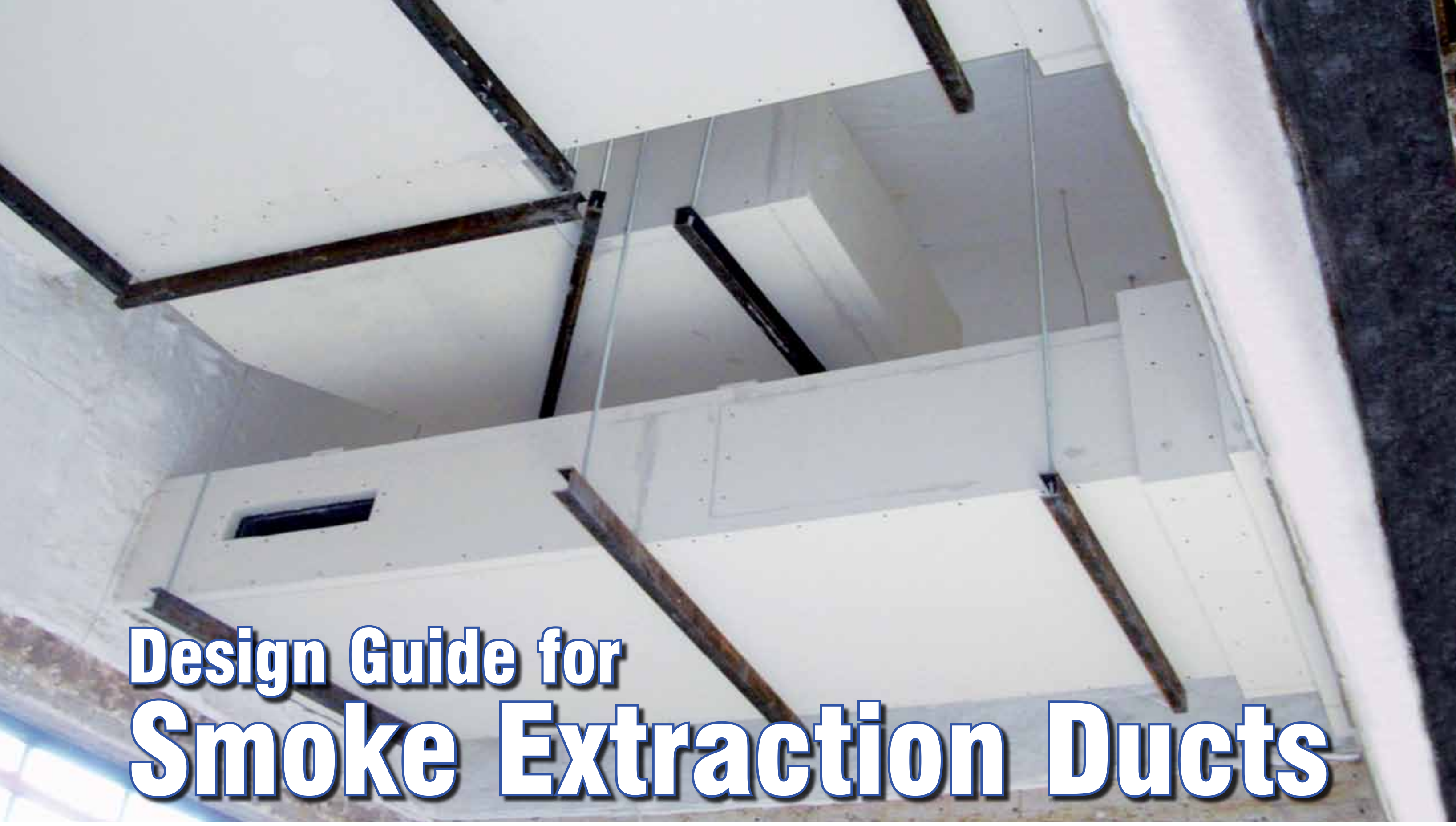

Design Guide for Smoke Extraction Ducts

By Ian R. Holt

Regional Technical Director, Promat International (Asia Pacific) Ltd.
Kuala Lumpur, Malaysia

Concluding Part 4

In the preceding parts of this series concerning fire resistant ventilation and smoke extract systems, we have covered the basics of where we use fire resistant duct systems, we have taken a broad look at the differences between fire test standards, and we went through the requirements for fire resistant and smoke extract ducts; - a simplified understanding of how ducts are tested, explaining why certain elements are important etc. We have discussed smoke extraction; - why, where, how. For the concluding part of the series, we will take a view of the design of fire resistant duct systems.

In this day and age, the importance of sustainable building practices and use of so called "green" materials grows almost daily. We see specifications for green materials in almost all tender documents nowadays, but sometimes we wonder whether such progress is actually thought through fully. We see that many of the products and systems included within today's environmentally friendly designs are in terms of their performance in fire, disasters waiting to happen. Many materials increase the fire load within a building dramatically, many materials when subjected to high temperature give off huge volumes of smoke and toxic fumes, as an example, a recent analysis of a test investigating the fire performance of a "green" building showed the following: "The air emissions from these tests contained 76 different components that were analyzed. In the sprinkled test, Anhydrous Ammonia, Carbon Tetrachloride, and Ortho-xylene were detected, while in the non-sprinklered test Ethanol, Hydrogen Chloride, Isopropyl Alcohol (IPA)and Bromoform were detected." There is a need to heighten the awareness of the specifiers as well as the fire services regarding issues related to sustainable development and construction. Sustainable development practices provide substantial, meaningful benefits to our society in the form of natural resource conservation and our long-term health and welfare. The importance of this movement is such that any negative unintended consequences must be avoided to assure the momentum of the effort isn't impeded.

Because many of the organisations that are focused on sustainability are working under the belief that public safety is addressed by other codes and standards, these organisations may not always recognize the safety implications of their practices. A number of organizations around the world today do recognize this fact and are taking steps to educate the industry of the issues and dangers they are inadvertently creating.

The terms "green" and "sustainable" are used interchangeably

About the Author

Ian R. Holt has worked in the fire protection industry for more than 20 years where he has been involved in the R & D of both materials and end-user systems for use as fire-resisting constructions. He has extensive experience of constructing and performing material and system fire tests in laboratories around the world and to most of the recognised national and international test standards. He has also been involved with a number of Asian countries in the drafting of building code standards related to fire protection.

in virtually all mainstream literature regarding high performance buildings. So the question persists: "How sustainable is a building if it isn't fire safe?" When posing the question to those who develop codes, standards, and rating systems for different levels of green construction, the responses vary. Some will say the focus of their efforts is to reduce the overall impact on our environment, not on fire safety. Others report that, while fires have a negative impact on the environment, they are rare and isolated events, so they don't try to address the issue in their work. In reality, fire prevention is omitted from these systems for a wide variety of reasons. Green regulations and rating systems are intended to recognize high-performance buildings from an environmental perspective. As fire safety considerations are considered basic rather than high performance requirements, they haven't been recognized at this point. Let us take this as a very simple point; how sustainable is a sustainable building when it has burned down?

The above may seem somewhat divorced from the subject of duct systems, but the two are somewhat interrelated. In Europe for instance, the problem is less pronounced due to the fact that the majority of fire resistant duct systems are required to provide full insulation when exposed to fire (in excess of 90% of duct systems for fire protection are required to provide an insulation performance.). However, within the Asia Pacific region, where the emphasis is more on price than performance, the installed duct system invariably offers an integrity-only performance. This is regardless of the fact that in almost all countries, the building regulations related to fire requires insulation performance. The vexing question is, given the fact that the heat radiation emission from non insulated ductwork often result in ignition of surfaces or materials located in close proximity to the surface, who is right –, Europe and elsewhere with their strict requirements for insulation, or Asia which appears to believe that in most instances this third element is unnecessary? Has a full and informed consideration of the problem been given or has cost been the overriding factor?

Ductwork in simple terms is a super highway that can travel through all areas and compartments of the building, its function being to allow the flow of air for, hopefully the full term of the life cycle of the building. Unfortunately, in the event of a fire in any compartment the action of the duct can become a super highway for fire and smoke. Often the action of the duct is dual purpose and that super highway is then required to extract the smoke from the fire area to provide a period of time sufficient to allow occupants to escape and the fire services to enter the building, for as we all know, it is almost certainly the smoke and the heat that kills rather than the actual fire. Thus the ducting creates that vital margin of safety.

It is the extraction of the smoke which can, if not handled correctly, become the very provider of transmitting the fire from one compartment to another! Under certain conditions flashover may well occur and, given sufficient duration of the fire, the heat generation within the duct can itself heat up the next compartment through which it is passing until the temperature near the duct reaches a level sufficient to ignite nearby combustibles and thus spread the fire from the duct to the compartment.

It is this element of fire safety which is addressed by the addition of the third discipline of insulation i.e. that the temperature within the duct must not be allowed to transgress the walls of the duct and so create the danger of excessive radiation from heat build up outside of the duct. The insulation criterion will also provide a very important fire safety element to individuals escaping through smoke darkened areas, or indeed the fire services who have to enter a fire racked building, both of whom are capable of coming into contact with the ductwork. Without the insulation criterion the ducts would have a surface heat level that is more than capable of causing severe burns to hands, arms and face.

The relevant complexity of any ductwork system which is passing different fire compartments and the relevance of the system's function in ambient as well as fire conditions can make the selection of a suitable ductwork system difficult. For particularly onerous conditions, e.g. where high impact strength is required or for use in aggressive environments, manufacturers have developed a range of systems using the high impact, high performance products.

Fire Testing Methods

To determine the fire resistance of ducts (without the aid of fire dampers) passing through or between compartments, the system should normally be tested or assessed in accordance with BS476: Part 24 or AS1530: Part 4. These standards have been written specifically for ventilation ducts, but guidance is also given in these standards on the performance requirements for "smoke outlet" ducts and "kitchen extract" ducts.

Although the following information refers to BS476: Parts 20 to 24, these details apply equally to AS1530: Part 4 in terms of the performance requirements. It should be noted, however, as detailed in the previous article, that there are substantial differences between the two standards in terms of testing methodology which greatly affect the results. It is not possible to simply transfer results from the AS1530: Part 4 test to BS476: Part 24 due to this huge difference in testing methods.

A part of a standard fire test, duct systems are exposed to external fire (also known as Duct type A) and one sample to both external AND internal fire (also known as Duct type B). Fans create a standard pressure difference and air flow and the ducts fire performance is assessed in both fan-on and fan-off situations. BS476: Part 24 expresses the fire resistance of ducts without the aid of dampers, in terms of stability, integrity and insulation.

Stability failure occurs when the suspension or fixing devices can no longer retain a duct in its intended position or when sections of the duct collapse. It should be noted that if a duct suffers extensive deformation, such that it can no longer fulfil its intended purpose, this would be classed as stability failure. For Duct type A, loss of pressure within the duct during testing is also construed as stability failure.

Integrity failure occurs when cracks, holes or openings occur in the duct or at any penetrations within walls or floors, through which flames or hot gases can pass. The effects on integrity of the movement and distortion of both restrained and unrestrained ducts are also included in the standard.

General Design Considerations

The following points are some of the factors which should be considered when determining the correct specification to ensure a ductwork system will provide the required fire performance.

1. **Required Fire Exposure**
   Ductwork systems which are located in more than one compartment should always be tested or assessed for their performance when exposed to the heating conditions described within BS476: Part 20. Reduced heating curves are generally only acceptable for certain of the system components, e.g. the fan. The performance of a ductwork system will vary depending on whether or not a fire could have direct access to inside the duct through an unprotected opening. If in doubt, one should assume direct access, i.e. the Duct B scenario described previously under Fire Testing Methods.
2. **Required Fire Performance**
   It is a general requirement that the ducts must satisfy all the relevant performance criteria of stability, integrity and insulation (and cross sectional area if a smoke extraction duct). However, the approval authority may accept relaxations on occasion. For example, if no combustible materials or personnel could be in contact with the duct, the authority may accept a reduced insulation performance.
3. **Supporting Structure**
   Care should be taken that any structural element from which the duct system is supported, e.g. a beam, floor or wall, must have as a minimum the same fire resistance as the duct system itself and must be able to support the load of the duct under fire conditions.
4. **Hanger Support**
   The supporting hangers, supports and their fixings should be capable of bearing the load of the complete ductwork system including any applied insulation material or other services suspended from it. Chemical anchors are generally not considered suitable. It is normally not advisable to use unprotected supports if the stress exceeds certain values and/or if hanger lengths exceed 2000 mm. Note that maximum length of unprotected hanger rods is often ignored as a limiting factor, however the expansion of rods when exposed to fire can, and do, lead to excessive deformation of the then unsupported duct, in turn leading to collapse. For any size of duct, the tensile stress in the steel hangers must not exceed 10N/mm^2 for fire resistance up to 120 minutes, or 6N/mm2 for fire resistance up to 240 minutes. The stress reduction ratio factors mentioned are based on BS5950: Part 1: 1990. Similar figures can be applied from AS4600.
   The method to calculate whether the diameter of the threaded rod is within the permitted stress level must be based on the *root* diameter of the rod. Equally, the maximum spacing of hanger support systems must be taken under consideration and these are all detailed in the relevant standard e.g. 30 minutes maximum 2500 mm centres, 240 minutes maximum 1500 mm centres. Equally, it must be noted that the stress levels referred to above apply to the threaded rod hanger supports themselves. The horizontal members have a differing level of applicable stress which will depend upon whether or not they are protected and the temperature to which they are exposed.
   The maximum centres refer to the greatest allowable distance between hanger support systems. However, it should be noted that in certain locations, bends for instance, additional supports at lesser centres should be considered. Where the hanger support system may exceed the limits, the remedial options are as follows:
   1) Increase the dimensions of the hanger support system, e.g. rod diameters etc,
   2) Reduce the centres of the hanger support system,
   3) Protect the hanger rods.
5. **Steel Ductwork**
   The steel duct must be constructed in accordance with the requirements of DW/144 – Specification for sheet metal ductwork – low, medium and high pressure/velocity air systems (published by the Heating and Ventilating Contractors' Association UK) or equivalent specification, e.g. SMACNA. The steel ducts must be constructed with rolled steel angle-flanged cross joints. It is recommended that longitudinal seams be formed using the Pittsburgh lock.
6. **Penetrations Through Walls & Floors**
   Care should be taken to ensure that movement of the duct in ambient or in fire conditions does not adversely affect the performance of the wall, partition or floor, or any penetration seal. It should be understood that where a duct passes through any compartment wall or floor or other type of separating element, the aperture between the element and the duct must be sealed in accordance with the system approved for use with the duct. In general this requires the use of a penetration seal constructed from materials and in such a manner to match the system used in the duct test programme. Penetrations seals are part of the tested duct system and the use of untested third party products are not permitted.
7. **Movement Joints**
   Movement joint details may be required for long lengths of duct, particularly where the duct spans across a movement joint in the floor or wall, or passes through floors and roof that may deflect at different rates. Proprietary systems for the creation of fire resistant movement joints are available from a wide range of sources.
8. **Air Flow & Leakage**
   The design of some fire resisting duct systems may need modification to meet DW/144 performance standards. All self supporting duct systems must meet requirements of DW/144 to the highest levels, provided the correct construction system is employed and all joints are correctly sealed in accordance with the system recommendations.
9. **Ductwork Functions**
   Most ductwork systems can fall into one or more of the following categories:
   - Ventilation and air conditioning;
   - Natural smoke extract;
   - Fan assisted smoke extract;
   - Pressurisation of escape routes and fire fighting lobbies.

   In the event of a fire, the function of a system can often change. For example, an air conditioning system could switch to become a fan assisted smoke extract duct. It is therefore essential that the performance requirements in both normal conditions and fire conditions are considered.
10. **Other Requirements**
    Acoustic performance, thermal insulation, water tolerance, strength and appearance can also be important considerations (See BS8313: 1989 Code of Practice for Accommodation of Building Services in Ducts).

continued on page 100

continued from page 98

Insulation failure occurs when the temperature rise on the outer surface of the duct outside the fire compartment exceeds 140°C (mean) or 180°C (maximum). The guidance in the standard also states that ducts lined with combustible materials or coated internally with fats or greases, e.g. kitchen extract, should also have this criterion for the inner surface of the duct within the fire compartment when the duct is exposed to external fire (Duct A).

For smoke extraction, the guidance in the standard states that the cross sectional area of a duct required to extract smoke in the event of a fire should not be reduced by more than 25% for the duration of the fire exposure.

Selection of Fire Protection System

Traditionally, all ductwork was fabricated from steel which normally had to be encased in a fire protection system when passing through a compartment wall or floor without the aid of a fire damper. In recent years, self-supporting systems without a steel liner have been introduced to extract smoke in the event of a fire through natural ventilation. Now, some self-supporting systems are available which can match the leakage and air flow performance of steel ducts in accordance with the DW144 standard up to Class C.

Any ductwork is required to maintain fire resisting compartmentation. A general requirement used to exist worldwide to ensure that a building is provided with a level of structural fire protection and compartmentation such that the building is capable of surviving a full burn out even if a sprinkler systems is installed. Nowadays, modern fire engineered designs tend to allow a trade off between active and passive systems. The older concept allows for the possibility of the sprinklers either failing to operate effectively due to poor maintenance, equipment failure or the inability to control an unexpectedly growing fire.

The rapidity and extent of the transmission of smoke through the ventilation system to remote parts of a building are of primary importance to life safety, particularly as the smoke is likely to contain toxic and/or noxious products of combustion.

Conclusion

So to go back to the original question posed; with regard to insulated or non insulated fire resistant ducting systems, who is right? Well, we believe our European colleagues are. By adding that third discipline of insulation to that of stability and integrity, if a fire does occur, then those responsible for the specification of the system can be fully and totally satisfied that they have taken every precaution possible to provide the maximum level of safety for the occupants of that building, and to ensure the safety of the emergency services that have the responsibility for safety and rescue of individuals.

To find an answer, it is hoped that the guides produced by companies and organisations with expertise in the field of fire engineering will go some way towards promoting a better understanding of this complicated subject and thus ensuring that the buildings we occupy are safer for all and that properly designed systems will be installed to make certain that ductwork can be used and will become a super highway for safety, and not for the movement of fire and smoke! ❖