



# The Impact of Fire Test Standards on How Fire Resistant and Smoke Extraction Ducts are Tested

**By Ian R. Holt**

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

**Part 3 of 4**

In the first two articles in this four part series, we overviewed where and why fire resistant and/or smoke extraction ducts are required in buildings. In doing so we also discussed the basics of design parameters for smoke extraction systems. The following outlines how fire resistant and smoke extraction ducts are tested, offering some comparisons between different test standards.

The science of fire testing is in itself quite complex, and none more so than the testing of duct systems, whether to ascertain fire resistance or their ability to effectively extract smoke under fire conditions. Indeed, there is far more to testing and system design than first appears apparent.

As we now know, smoke and toxic gases generated by most fires cause more fatalities than the actual fire. Not surprisingly, the way that buildings cope with smoke and smoke extraction is a guiding principle for many building professionals and fast becoming a central component in building design everywhere. This is supported by a research of knowledge in the behaviour of smoke, its properties and how it can be effectively managed by intelligent building design.

Ductwork used for smoke extraction purposes must be of a standard at least capable of withstanding the anticipated smoke temperature as calculated by the fire design engineer. If it passes through a fire-resisting barrier, ductwork must also be capable of satisfying the fire resistance requirements to the same specification as the barrier itself.

## **Fire-Resisting Ductwork Also Required To Maintain Fire-Resisting Compartmentation**

A general requirement exists worldwide to ensure that a building is provided with a level of structural fire protection

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### **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.

and compartmentation such that the building is capable of surviving a full burn-out even if a sprinkler system is installed.

This concept allows for the possibility of the sprinklers either failing to operate effectively due to poor maintenance, equipment failure, water shortage or the inability to control an unexpected and rapidly growing fire. Therefore, if a smoke extract or any ventilation ductwork passes through a fire-resisting compartment barrier, it is necessary to ensure that both fire and smoke cannot readily spread from one area of the building to another via the ductwork.

For normal ventilation ductwork, one of the following three methods may be used to limit fire spread:

- Fire protection of existing galvanised sheet metal steel ductwork.
- Construct the duct from a proprietary fire-resisting material.
- Install smoke or temperature operated fire dampers in ductwork wherever a compartment boundary is crossed (unsuitable for smoke extract ductwork).

The fire resistance of ductwork is required for three reasons:

- Prevent fire inside the duct spreading to another fire compartment (in test terms known as Duct Type B).
- Prevent fire outside the duct breaking into the duct and thus entering another fire compartment, e.g. via an inlet grille.
- To prevent fire outside the duct breaking into the duct and then breaking out into another fire compartment (in test terms known as Duct Type A).

In most cases the duct will be required to provide fire resistance to both external (i.e. outside the duct) and internal (i.e. inside the duct) fire. There are occasions, however, when resistance will only be required to fire inside the duct. Where such occasions are identified then ductwork resistant only to fire inside the duct can be used.

It should also be noted that the standard of fire resistance required of a duct may also vary.

## Performance Criteria For Fire-Resisting Ductwork

British Standard 476: Part 24: 1987 details the “Methods for determining the fire resistance of ventilation ducts, smoke and kitchen exhaust ducts”. The performance criteria are Stability, Integrity and Insulation.

A fire resisting ductwork is deemed to have failed Stability if one of the following occurs:

- Fire resisting ductwork inside the furnace exposed to

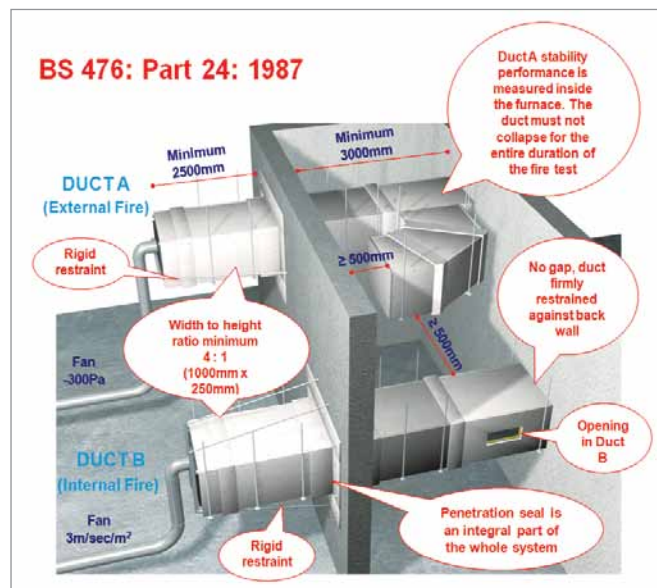


Figure 1: Testing arrangement as per BS 476:Part 24, 1987

external fire (called Duct A in the standard) collapses in the furnace in such a manner that the duct no longer fulfils its intended function.

- Either length of Duct A or the length of fire resistant ductwork exposed to internal and external fire (called Duct B in the standard) within the furnace collapses on the outside of the furnace, in such a manner that the duct no longer fulfils its intended function.
- The presence and formation in the test specimen of cracks, holes or other openings outside the furnace through which flames or hot gases can pass shall constitute Integrity failure.

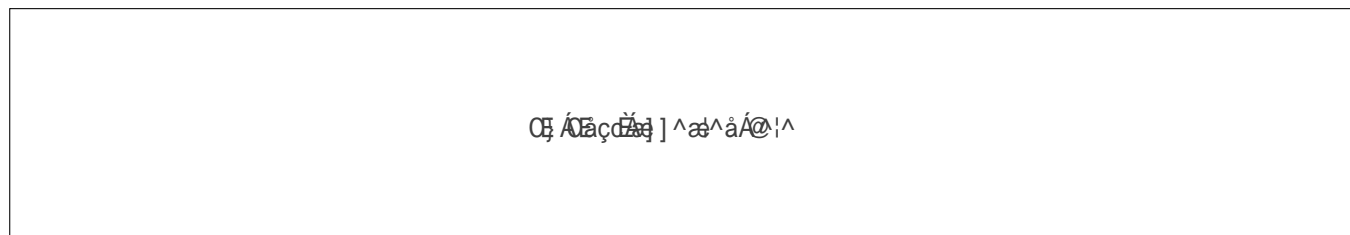
Insulation failure is deemed to have occurred when the temperature rise above initial ambient temperature in the laboratory on the unexposed surface of the test specimen (for both Ducts A and B) outside the furnace exceeds either.

- 140°C as an average value or
- 180°C as a maximum value read by any surface thermocouple.

## Insulation

In some cases, even when a duct needs to be fire-resisting, it is not always necessary for it to fully comply with the insulation criterion of the fire resistance test. However, it must satisfy the insulation criterion for a fire inside the duct in the following circumstances:

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- The duct passes through a circulation or means of escape area where it is hazardous to the escape of people from the building and/or
- The duct is or could come into contact with combustible or inflammable materials. It is particularly important to ensure that sound or thermal insulation materials to ductwork will not be raised to ignition temperature as a result of heat conduction through the ductwork.

## Penetration Seals

Where ductwork passes through a compartment wall or floor, fire separation of the wall or floor must be effectively maintained. This is usually achieved in one of two ways:

- For fire resistant ducts a penetration seal is fitted between the duct and the wall or floor. The penetration seal and the ductwork are considered as one integral system and must be the same as that tested or assessed in accordance with BS 476: Part 24: 1987.
- For non-fire resistant ductwork, a fire damper must be fitted in the plane of the wall or floor. The damper and associated penetration seal must be installed to a procedure substantiated by test or assessment. It is important to note that the damper must be mounted in the wall or floor and, similarly, be supported/ restrained independently of the ducts.

Where a fire resistant duct adjoins a damper fitted in a wall or floor, the penetration seal to the wall or floor must be installed as above. The fire resistance test for ducts in BS 476: Part 24: 1987 is designed to evaluate the fire performance of the duct penetration seal system through a wall or floor construction (the fire separating element) as well as the fire performance of the duct system itself.

It is also essential to understand that successful test on a penetration seal fitted around one type of duct construction does not mean that the penetration seal is suitable for use with a different type of duct construction. Usually the penetration seal will be suitable for duct sizes smaller than that tested, but the construction of the duct may have to be modified or the duct locally strengthened at the penetration, for duct sizes larger than that tested.

## Comparison of Standards

Most of the professional building and fire protection industries look to either AS 1530: Part 4: 2005 and BS 476: Part 20: 1987 or both as benchmarks for fire testing ductwork.

There are as many, seemingly logical explanations of standards as there are so-called fire science professionals

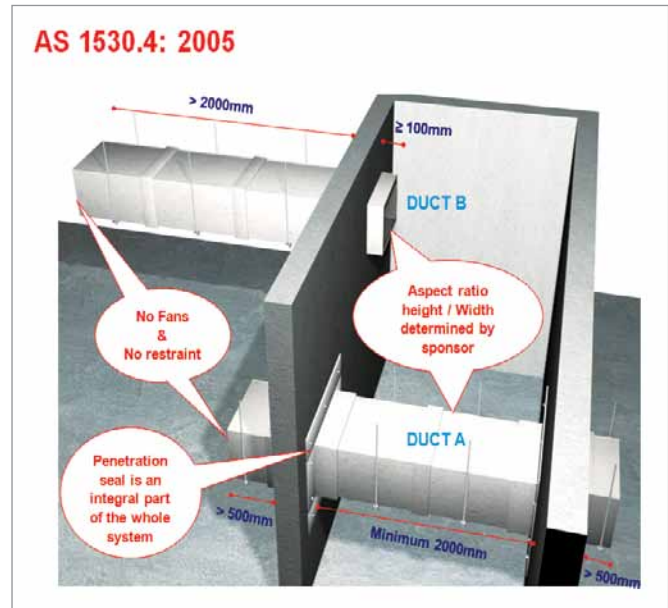


Figure 2: Testing arrangement as per AS 1530: Part 4, 2005

willing to extrapolate them. Indeed, there are many occasions where, regrettably, these are merely subjective opinions.

One caveat, however, is that following comparison is NOT subjective but rather is a comment on performance based on factual evidence from testing the same systems to both regimes.

Space limitations mitigate against lengthy explanations but in many ways the different standards are comparable.

The following focus is therefore on the main areas which the different methods of testing can effect the performance of the duct system.

It is also important to note that ISO 6944 and BS 476: Part 24: 1987 are in fact identical at present. However, ISO 6944 is in the process of being updated to reflect recent changes to EN 1366.

Both AS 1530: Part 4: 2005 and BS 476: Part 20: 1987 utilise gas fire furnaces, and follow a similar time/temperature curve.

The heating regime in AS 1530 is an expression of the temperature rise in the furnace while in BS 476 it is assumed that the initial furnace temperature is 20°C irrespective of the actual furnace temperature.

This means that AS – if tested on a warm day with the furnace at the 40°C maximum – the furnace temperature curve could well be slightly more onerous in technical terms

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but in practical terms would have zero effect in terms of heat exposure.

In AS the initial furnace temperature can be within the range 10°C to 40°C whereas in BS the limit is 5°C to 35°C. The difference is minor and would not have any great effect on the results.

The parameters outlining the accuracy of control of the furnace temperature are not appreciably different and therefore specimens tested in accordance with both standards would be expected to be exposed to very similar heating regimes.

The furnace thermocouples specified in AS 1530: Part 4 are type K, mineral insulated metal sheathed with a stainless steel sheath having a wire diameter of 1mm and an overall diameter of 3mm.

The measuring junction protrudes 25mm from the supporting heat resistant tube.

On the other hand, the furnace thermocouples specified in BS 476: Part 20 can be of two types, as follows:

- Bare chromium /nickel aluminium wires, 0.75mm to 1.5mm in diameter, welded or crimped together at their ends and supported from each other in a twin bore porcelain insulator, except that the wires for 25mm approximately from the weld/crimp are exposed and separated from each other by at least 5mm.
- Nickel chromium/nickel/aluminium wires, contained within a mineral insulation and in a heat resisting steel sheath of diameter 1.5mm, the thermocouple hot junction protrudes a minimum of 25mm from a porcelain insulator. The assembly has a response time on cooling in air of not greater than 30 seconds.

The BS 476 guideline, unlike AS 1530, requires all furnace thermocouples to be replaced after six hours of usage. The furnace thermocouples are required to be positioned relative to the exposed face of the specimen such that the distance is  $100\text{mm}^3 \pm 10\text{mm}$  in both standards.

The response of the different thermocouple types to the furnace conditions specified in the two standards is generally therefore not expected to significantly affect the outcome of any fire tests.

In fact, a variation due to the difference in heat transfer conditions between furnaces is more likely to influence the results rather than the above minor differences.

The furnace pressure required under AS 1530: Part 4 (Section

9 relating to the fire testing of ducts) is not specified and in fact both the ducts type A (external fire) and B (internal fire) are not pressurised in any way.

They rely instead on natural convection and radiation to take the furnace gases into the duct systems whereas in BS 476: Part 24 (relating specifically to ducts) the duct type A is subject to an under pressure of  $300\text{Pa} \pm 10\text{Pa}$ .

More significantly, the pressure fluctuations are recorded throughout the test as a measure of air leakage through the duct. The duct type B is attached to a fan which has to draw the hot furnace gases from inside the furnace at a rate of 3m/s.

The negative pressure in Duct Type A under BS results in the top and bottom of the duct to bow into the duct itself. This in turn results on extra stress being place onto a.) the duct joints, both flanges and at the corners and b.) onto the penetration seal which is forced to cope with an ever widening gap. As the bow increases this aperture grows wider and longer. The penetration seal detail is thus required to be more reactive than one tested under AS.

The testing of a duct type A is therefore far more onerous under the conditions of BS 476: Part 24 than under the conditions of AS 1530: Part 4. Failure of integrity especially of the penetration seal, usually occurs much sooner under a BS regime than under AS.

Furthermore, under AS 1530, the duct type A passes though the furnace and protrudes at either end, allowing airflow down the duct through the furnace. This has a cooling effect on the duct and as a result the duct more likely to have a prolonged stability and integrity.

In the equivalent BS test, the duct is exposed for a minimum 3000mm length within the furnace. The duct A is closed at one end inside the furnace and the other end is closed with a fan attached to extract air causing the under pressure described above.

In such enclosed ducts, because the fan is attempting to draw the furnace gases into the duct, heat exposure is much more severe and insulation failure is more likely to occur earlier than in a test to AS.

In the AS test, a Duct Type B specimen is positioned outside the furnace with only 2000mm on the unexposed face and 100mm inside the furnace. There are no fans attached and the test relies on the radiation from the furnace and heat convection to raise the temperature inside the duct.

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The AS standard stipulates no more than a 250°C differential in furnace temperatures. This difference, by the way, applicable in the 1997 version of AS 1530:4 but no longer applied in the 2005 version of the standard, can create great differences in performance between the 1997 and 2005 versions of the standard, particularly when the interior of the Duct Type B is subjected to lower exposure temperature.

The ducts tested under AS1530 are not restrained against movement, so expansion can take place without affecting the system under test. Under BS 476 both ducts A and B are restrained against longitudinal expansion both inside and outside the furnace. Because under BS both ducts are exposed inside the furnace, this restraint causes the duct to bow and distortion of the system to take place; again this produces enormous stress at the penetration seal and on the joints between the individual duct sections in excess of what would be experienced under the AS regime and therefore it could be considered that BS in this aspect is far more onerous than the AS test.

## Installation and Workmanship

There are numerous other technical differences than those outlined above.

At the end of the day however, there is one area which can effectively negate and undermine all other good intentions to design and test proprietary fire protection systems and that is implementation.

If the contractor uses sub-standard materials, decides to circumvent the construction design specification, delivers poor quality workmanship or chooses to use unproven materials and systems, the system is surely doomed.

If fire test and by progression worksite installation is analogous with the end of the food chain – more often than not carried out by the workers with the lowest levels of education and little understanding of the importance of the ductwork they are erecting – they potentially jeopardise the efficacy of the whole system.

There is simply no point investing time and effort designing a smoke extraction strategy only to deliver poor craftsmanship and install substandard systems which fail at the first whiff of fire or hot smoke! ❖

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