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The Facts About Fire & Smoke Dampers

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Express Towers on fire in Mumbai

Absence of adequate test facilities hampers the gr growth owth of the market and compels users to install pr products oducts that can fail to perform during a fir fire

Ducted air distribution systems in a centrally air conditioned building act as an easy passage for spread of fire and smoke when a fire occurs due to any reason. Fire dampers, smoke dampers or combination fire smoke dampers play a vital role in the management of fire and smoke in these cases.

Twenty years ago, the importance of these dampers, their construction, their testing, proper placement and installation in an air distribution system was not well appreciated or understood by many system designers, contractors and even the fire departments of large cities. Several disastrous fires that occurred during this 20 year span in New Delhi (Vigyan Bhavan, Hotel Vasant Continental, Gopala Towers, Ansal Bhavan, Uphaar Cinema) and

Mumbai (State Bank of India, Express Towers) made the fire departments sit up and study the reasons for the fast spread of such fires and the loss of life.

At the State Bank of India building, Mumbai the firemen would finish putting off a fire, say on the 8th floor, and notice another fire starting on the 10th floor. Much later it was realized that a common shaft fed conditioned air to several floors from a common air handling unit and fire would spread from one floor to another via this common shaft. The most common insulation material used on ducts, in those early days, was Thermocole (a trade name for Styrofoam) wrapped with jute fabric, which could catch fire very fast and spread even faster. Smoke filled the staircase making entry and exit from the fire-affected building most difficult.

The National Building Code (NBC), which has a section devoted to air conditioning systems under “Building Services” was last published in 1983 and had very few recommendations on fire dampers and smoke management. Work started a year ago on the latest revision of this code and a group of experts from ISHRAE was formed for this task, which has been completed, and the draft revision is presently getting ready for printing. The relevant section is reproduced below:

Extracts from draft revision of National Building Code

•Air conditioning and ventilating systems shall be so installed and maintained as to minimize the danger of spread of fire, smoke or fumes from one floor to the other or from outside to any occupied building or structure

•Air conditioning and ventilating systems circulating air to more than one floor or fire area shall be provided with dampers designed to close automatically in case of fire and thereby preventing spread of fire or smoke and shall be in accordance with the accepted standard. Such a system shall also be provided with automatic controls to stop fans in case of fire, unless arranged to remove smoke from a fire, in which case these shall be designed to remain in operation.

• Air conditioning system serving large places of assembly (over 1,000 persons), large departmental stores or hotels with over 100 rooms in a single block shall be provided with effective means for preventing circulation of smoke through the system in the case of a fire in air filters or from other sources drawn into the system, and shall have smoke sensitive devices for actuation in accordance with the accepted standards.

• From fire safety point of view, it shall be preferable to provide separate air handling units for the various floors so as to avoid the hazards arising from spread of fire and smoke through the air conditioning ducts. The requirements of air conditioning ducts shall be in accordance with good practice.

Pressurization of staircases (protected escape routes)

• Though in normal building design, compartmentation plays a vital part in limiting the spread of fire, smoke will readily spread to adjacent spaces through the various leakage openings in the compartment enclosure, such as cracks, openings around pipes ducts, airflow grills and doors, as perfect sealing of all these openings is not possible. It is smoke and toxic gases, rather than flame, that will initially obstruct the free movement of occupants of the building through the means of escape (escape routes). Hence, the exclusion of smoke and toxic gases from the protected routes is of great importance.

• Pressurization is a method adopted for protected escape routes against ingress of smoke, especially in high-rise buildings. In pressurization, air is injected into the staircases, lobbies or corridors, to raise their pressure slightly above the pressure in adjacent parts of the building. As a result, ingress of smoke or toxic gases into the escape routes will be prevented.

• The pressurization levels for staircases should be as under :

Building Height	Pressurization Level	
	Reduced operation (Stage 1 of a 2-stage system) (Pa)	**Emergency Operation (Stage system or Single stage system)** (Pa)
Less than 15 m	8	50
15 m or above	15	50

If possible, the same levels shall be used for lobbies and corridors, but levels slightly lower may be used for these spaces if desired. The difference in pressurization levels between staircase and lobbies (or corridors) shall not be greater than 5 Pa.

Basements

• Each basement shall be separately ventilated. Vents with cross-sectional area (aggregate) not less than 2.5 percent of the floor area spread evenly around the perimeter of the basement shall be provided in the form of grills, or breakable stallboard lights or pavement lights or by way of shafts. Alternatively, a system of air inlets shall be provided at basement floor level and smoke outlets at basement ceiling level. Inlets and extracts may be terminated at ground level with stallboard or pavement lights as before, but ducts to convey fresh air to the basement floor level have to be laid. Stallboard and pavement lights should be in positions easily accessible to the fire brigade and clearly marked 'SMOKE OUTLET' or 'AIR INLET' with an indication of area served at or near the opening.

• In multi-storey basements, intake ducts may serve all basement levels, but each basement level, and basement compartment shall have separate smoke outlet duct or ducts.

• Mechanical extractors for smoke venting system from lower basement levels shall also be provided. The system shall be of such design as to operate on actuation of heat/smoke sensitive detectors or sprinklers, if installed, and shall have a considerably superior performance compared to the standard units. It shall also have an arrangement to start it manually.

• Mechanical extractors shall have an internal locking arrangement, so that extractors shall continue to operate and supply fans shall stop automatically with the actuation of fire detectors.

• Mechanical extractors shall be designed to permit 30 air changes per hour in case of fire or distress call. However, for normal operation, air changes should be as per schedule given elsewhere in this code.

• Mechanical extractors shall have an alternative source of supply.

•Ventilating ducts shall be integrated with the structure and made out of brick masonry or reinforced cement concrete as far as possible and when this duct crosses the transformer area or electrical switchboard, fire dampers shall be provided.

• All floors shall be compartmented with area not exceeding 750 m^2 by a separation wall with 2 h fire rating, for floors with sprinklers the area may be increased by 50 percent. In a long building, the fire separation walls shall be at distances not exceeding 40 m. For departmental stores, shopping centers and basements, the area may be reduced to 500 m^2 for compartmentation. Where this is not possible, the spacings of the sprinklers shall be suitably reduced. When reducing the spacing of sprinklers, care should be taken to prevent spray from one sprinkler impeding the performance of adjacent sprinkler head.

Service ducts/shafts

1. Service ducts and shafts shall be enclosed by walls of 2 h and doors of 2 h, fire rating. All such ducts/ shafts shall be properly sealed and fire-stopped at all floor levels.
2. A vent opening at the top of the service shaft shall be provided having between one-fourth and onehalf of the area of the shaft.

Air-conditioning shall confor conform m to the following :

1. Escape routes like staircases, common corridors, lift lobbies, etc, shall not be used as return air passage.
2. The ducting shall be constructed of substantial gauge metal in accordance with good practice.
3. Wherever the ducts pass through fire walls or floors, the opening around the ducts shall be sealed with materials having fire resistance rating of 1h.
4. As far as possible, metallic ducts shall be used even for the return air instead of space above the false ceiling.
5. Where plenum is used for return air passage, ceiling and its fixtures shall be of non-combustible material.
6. The materials used for insulating the duct system (inside or outside) shall be of non-combustible material. Glass wool shall not be wrapped or secured by any material of combustible nature.
7. Area more than 750 m^2 on individual floor shall be segregated by a fire wall and automatic fire dampers for isolation shall be provided.
8. Air ducts serving main floor areas, corridors, etc, shall not pass through the staircase enclosure.
9. The air handling units shall be separate for each floor and air ducts for every floor shall be separated and in no way inter-connected with the ducting of any other floor.
10. If the air handling unit serves more than one floor, the recommendations given above shall be complied with in addition to the conditions given below :
    a. Proper arrangements by way of automatic fire dampers working on fusible link/or smoke detector for isolating all ducting at every floorfrom the main riser shall be made.

b. When the automatic fire alarm operates, the respective air handling units of the airconditioning system shall automatically be switched off.

Note: *Fusible link operates on heat detection system.*

11. The vertical shaft for treated fresh air shall be of masonry construction.
12. The air filters of the air handling units shall be of non-combustible materials.
13. The air handling unit room shall not be used for storage of any combustible materials.
14. Inspection panels shall be provided in the main trunking to facilitate the cleaning of ducts of accumulated dust and to obtain access for maintenance of fire dampers.
15. No combustible material shall be fixed nearer than 150 mm to any duct unless such duct is properly enclosed and protected with non-combustible material (glass wool or spunglass with neoprene facing enclosed and wrapped with aluminium sheet) at least 3.2 mm thick and which would not readily conduct heat.
16. Fire Dampers
    a. These shall be located in conditioned air ducts and return air ducts/passages at the following points :
        i. At the fire separation wall.
        ii. Where ducts/passages enter the central vertical shaft.
        iii. Where the ducts pass through floors, and
        iv. At the inlet of supply air duct and the return air duct of each compartment on every floor.

    b. The dampers shall operate automatically and shall simultaneously switch off the airhandling
    fans. Manual operating facilities shall also be provided.

    Note: *For blowers, where extraction system and dust* accumulators are used, dampers shall be provided.

    c. Fire/smoke dampers (for smoke extraction shafts) for buildings more than 24 m in height.

    For apartment houses: In non-ventilated lobbies/corridors operated by fusible link/smoke detectors and with manual control.

    For other buildings: On operation of smoke detection system and with manual control.

    d. Automatic fire dampers shall be so arranged as to close by gravity in the direction of air movement and to remain tightly closed on operation of a fusible link/smoke detector.

The fire departments of all major cities have also framed standards of compliance that must be followed before a new building can be declared suitable for occupancy. Relevant extracts from such standards given by the Delhi Fire Service and the Mumbai Fire Department for a hotel building in each city are mentioned below.

While the general level of awareness of fire and smoke dampers among HVAC system designers has certainly improved, a lot more needs to be done at the level of contractors who, generally, prefer to buy the lowest price damper and install it with a minimum concern for the safety of people and property during a fire. What makes the problem of safety even worse is that all manufacturers of fire and smoke dampers do not necessarily have their dampers tested by a reliable institute, nor does the NBC or fire department insist on such a test and a certificate to that effect.

There is only one institute in India, CBRI Roorkee (Central Building Research Institute), which has a testing facility for a fire damper as per Clause 10 of UL 555 – 1995 (UL or Underwriters Laboratories is an American organisation) but other tests required by UL for a fire damper under UL 555 and UL 555S for leakage ratings of smoke dampers, are just not available. See details of various tests required by UL Standards.

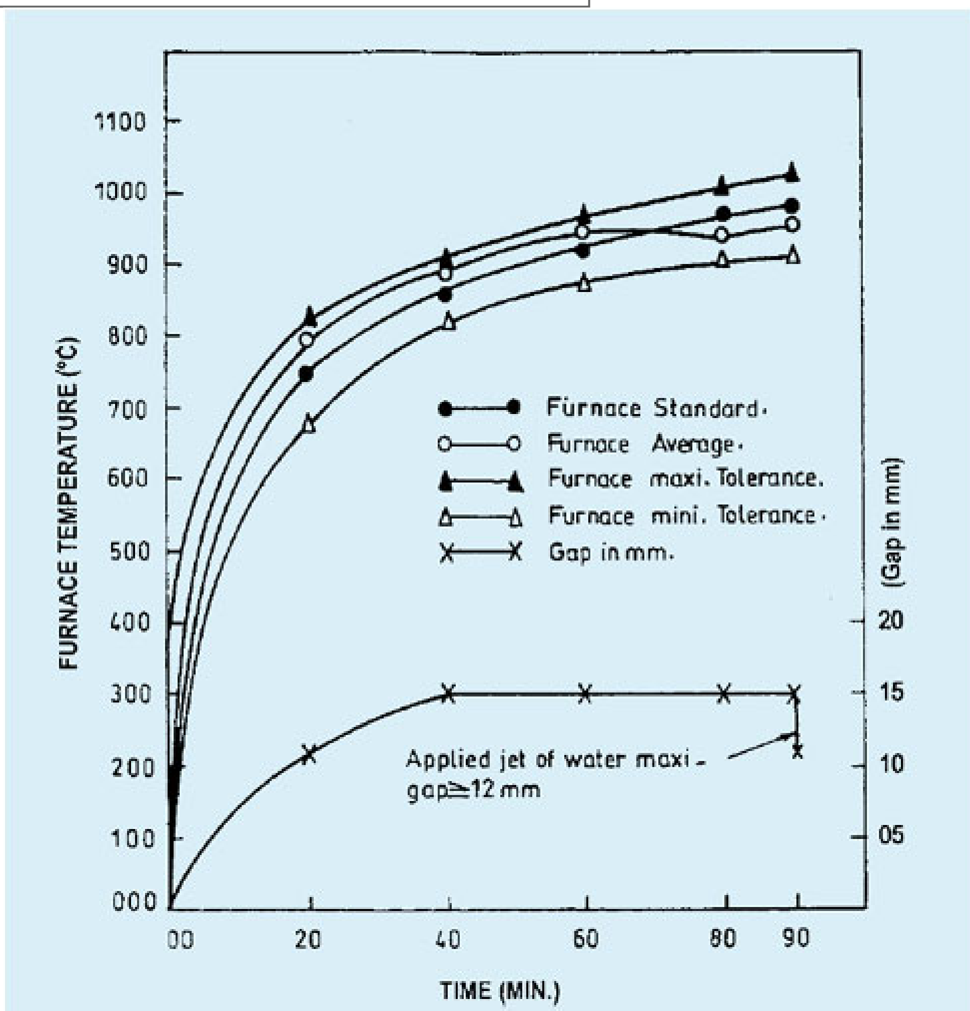
CBRI, Roorkee carries out a Fire Endurance Test and a Hose Stream Evaluation Test, as per details below:

Fire Endurance T Test est car carried ried out by CBRI

Fire Endurance Test at CBRI, Roorkee
Photo courtesy of Caryaire Equipments

Under this test the specimen is subjected to standard heating conditions in a furnace which can run through out the evalution period at atmospheric pressure . The damper assembly is exposed to fire to conform to a standard time-temperature pattern as given below :

Time (min.)	Furnace Temperature rise (°C)
05	538
10	704
30	843
60	927
90	978



Furnace Time-Temperature Curve and Maximum Gap between flaps during the evaluation in downstream position of multiflap fire damper

Extract from letter of Delhi Fire Service for a hotel in New Delhi

Air conditioning

The following must be ensured in respect of the air-conditioning system :

1. All ducts must conform to IS 655 Metal Air Ducts.
2. Wherever the ducts pass through fire walls or floors, the opening around the ducts must be sealed with fire resisting materials, such as asbestos rope, vermiculite concrete etc.
3. Air ducts serving the main floor areas, corridors etc. must not pass through the staircase enclosure.
4. The doors of the air handling unit rooms must be suitably modified or replaced so as to ensure that each door has a fire resistant rating of not less than one hour.
5. The ceiling and all its fixtures must be of non-combustible material. However, the existing ceiling may be permitted to be retained if the same is treated on both sides with an approved fire resistant composition.
6. The air filters of the air handling units must be of non combustible materials.
7. The air handling unit room must not be used for storage of any combustible material.
8. No combustible material shall be fixed nearer that 15 cm to any duct unless such ducts is properly enclosed and protected with non combustible material (glass, wool or spunglass) with neoprene facing enclosed and wrapped with aluminium sheet atleast 3.2 mm thick and which would not readily conduct heat.
9. The fire dampers shall be provided in the ducts.

In kitchen extract ducts for pans & fryers shall be independent of any other work or any obstruction. Pans & fryers shall be provided with lid. Grilling and frying equipments in use shall not leave unattended. Main electrical switches and gas stop codes in a kitchen shall be positioned on an exit route and shall be clearly marked / labelled.

The mechanism for pressurising the staircase, shaft lift, lift lobby / corridor shall be so installed that the same shall be operated automatically and also with manual operation facilities, when the automatic fire detection/fire alarm system or sprinkler system actuate.

Extract from letter of Mumbai Fire Dept. for a hotel in Mumbai

AC system

1. The AC system shall be of chilled water type.
2. As far as possible, guest rooms shall be provided with separate coil units.
3. Escape routes like staircases, common corridors, lift lobbies, etc. shall not be used as return air passages.
4. The AC ducts shall be constructed of substantial metal gauge in accordance to IS 655 : 1963 for Metal Air Ducts (revised).
5. Wherever ducts pass through walls, the opening around the duct shall be sealed with fire resisting material such as asbestos rope or vermiculite concrete.
6. For return air also, metal ducts shall be used.
7. The materials used for insulating the duct (inside or outside) shall be of non-combustible material such as glass cool, spunglass with neoprene facing, etc.

8. AHUs, shall be separate for each floor/areas, as shown on the plan and they shall not be in any way interconnected with the ducting of any other floors or areas.
9. Air filter of AHU shall be of non-combustible materials.
10. AHU rooms shall not be used for storage of any combustible material.
11. The materials used for false ceiling and its runners and suspenders shall be of non-combustible type.

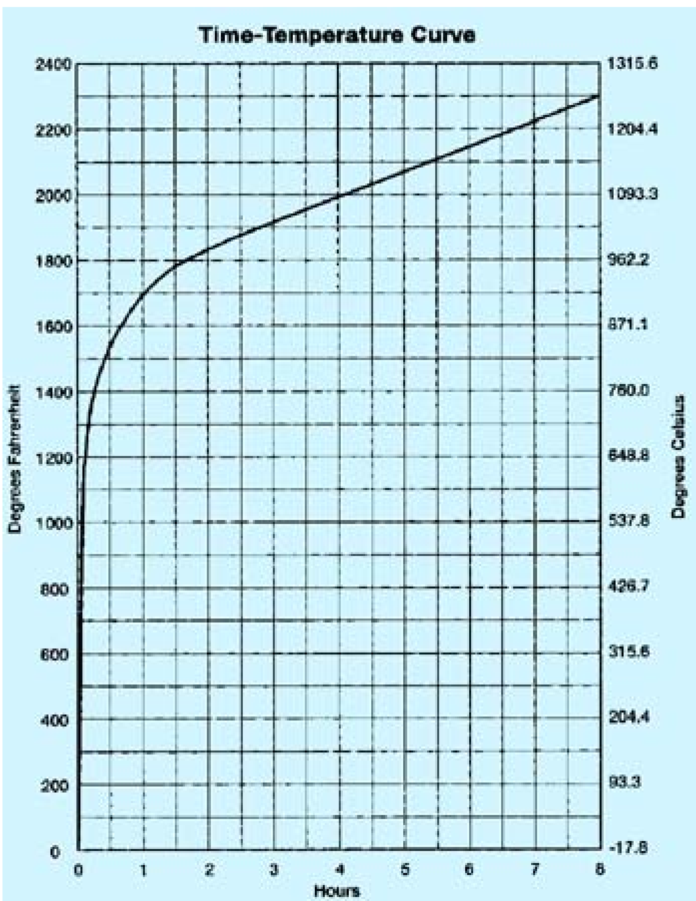
UL standards for testing and rating of fire smoke dampers

(courtesy Greenheck catalog)

Two UL standards provide the basis for testing, qualifying, and rating Fire Smoke Dampers. These two UL Standards are :

UL 555 Fire Dampers

UL 555S Leakage Rated (Smoke) Dampers for Use in Smoke Control Systems



Here is a summary of the major tests required to qualify dampers to these standards:

Fire endurance test and hose stream test (UL 555).

Dampers are exposed to a standard test fire for a period of either 1½ or 3 hours. This standard test fire is controlled to follow the time temperature curve illustrated. Immediately after conclusion of this fire test, the dampers are subjected to a high pressure hose stream test during which water, at a nozzle pressure of 30 psi for 1½ hour dampers and 45 psi for 3 hour dampers, is applied to the dampers from a distance of 20 ft. The hose stream test provides an extreme shock that ensures the dampers are structurally strong enough to withstand the rigors of the severest fire conditions.

Operational reliability cycle test (UL 555S).

Fire Smoke Dampers intended for operation by gravity or spring force (not driven by an actuator) must be cycled open and closed 250 times. Fire Smoke Dampers that are driven by an electric or pneumatic actuator must be cycled open and closed (by their actuator) 20,000 times. If the Fire Smoke Damper is also intended for use as a volume control damper, it must be cycled open and closed (by its modulating actuator) 100,000 times. These operational cycling tests are accomplished prior to the temperature degradation and leakage tests (described below) and ensure that the damper will function reliably after repeated operations.

Salt spray exposure test (UL 555 & UL 555S).

A damper sample is exposed to salt spray in a test chamber for a period of 120 hours. After this exposure, the damper must close (and latch if a latch is provided). This test demonstrates a damper's ability to function after a more severe fouling than the damper is likely to experience during its
intended application.

Operational performance test (UL 555 & UL 555S).

A damper is subjected to airflows and pressures and must demonstrate its ability to operate in the manner expected by its configuration and intended application. Smoke Damper and Combination Fire Smoke Damper actuators must operate the dampers open and closed three times and Combination Fire Smoke Dampers must also close as they would if their heat responsive device (RRL or fusible link) would operate. A damper model's airflow velocity and differential pressure ratings are based on the velocity and pressure conditions against which the damper demonstrates its ability to operate.

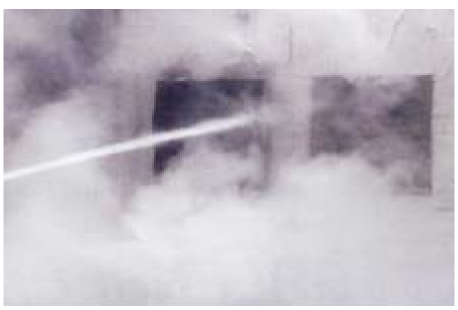
Temperature degradation and cycling test (UL 555 & UL 555S).

A damper with an actuator that has previously been subjected to the **Operational Reliability Cycle Test** (described above) is exposed to an elevated temperature of 250°F minimum (or higher in multiples of 100°F) for a period of 30 minutes. After this 30 minutes exposure and while still at the elevated temperature, the damper actuator must operate the damper open and closed three times. Time of operation cannot exceed 75 seconds for any of the open or closed operations.

Leakage test (UL 555S).

At least three damper sizes of each model being tested (minimum width by maximum height, maximum width by minimum height, and maximum width by maximum height) that have previously been subjected to both the **Operational Reliability Cycle Test** and the **Temperature Degradation and Cycling Test** must be tested for leakage. The minimum airflow and pressure ratings of dampers shall be 2000 fpm and 4 in. w.g. Ratings shall be set in 1000 fpm increments from the minimum airflow and in 2 in. w.g. increments from the minimum pressure. Leakage testing must be conducted at 400 fpm higher than the rated airflow and 0.5 in. w.g. higher than the rated pressure. A damper's leakage rating is based on the worst case performance of the three damper sizes tested.

Hose Stream Evaluation Test carried out by CBRI



Hose Stream Evalution Test at CBRI, Roorkee
Photo courtesy of Caryaire Equipments

A jet of water is applied to the exposed face of the fire damper and any change in the gap between the various flaps is observed. The curve shown above also indicates the maximum gap noted in the damper blades at different times of the test in downstream position. Also indicated on the curve is the reduction of gap in case of one blade from 15 mm to 12 mm after application of Hose Stream. Basically this test is done to test the structural capability of the fire damper.

Conclusion

Since the safety of life and property, in any occupied building that is air conditioned, is vitally important, it would be desirable if industry (manufacturers of fire and smoke dampers) would initiate a dialogue with CBRI to undertake the remaining tests required by UL Standards, with part finance coming from industry and part from the Government by way of grants. Equally important, is that until such an industry initiative takes place and all test facilities are in place, specifiers and contractors take some basic precautions, such as insisting on CBRI tests and approval, as existing today, and installation practises in line with international standards.