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STUDY ON ELIMINATING FIRE DAMPERS TO MAINTAIN PROCESS CONFINEMENT (U)

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ABSTRACT

The DOE General Design Criteria[1] for the Defense Waste Processing Facility (DWPF) at the Westinghouse Savannah River Site (WSRS) requires the NFPA National Fire Codes to be incorporated into the design and simultaneously maintain process confinement integrity to prevent the release of radioactivity. Although the NFPA Standard for the Installation of Air Conditioning and Ventilation Systems, NFPA 90[2], requires fire dampers (FD) in HVAC duct penetrations of two hour rated fire barriers, closure of fire dampers at DWPF may compromise the integrity of the process confinement system. This leads to the need for an overall risk assessment to determine the value of 39 fire dampers that are identified later in the study as capable of a confinement system upset.

The issue of process confinement (life safety) involves both structures and ventilation systems as detailed in DOE Order 6430.1A, 1530-99.0, p. 15-13 as follows:

To protect the integrity of process confinement systems, fire protection systems shall include the following features:

- Automatic and redundant fire protection devices.

- A fire-extinguishing system to rapidly remove heat produced by fire to prevent or minimize the pressurization of a process confinement and to rapidly extinguish a fire to minimize the loading of ventilation system filters with combustion products.

- The introduction of the extinguishing agent in a way that does not result in overpressurization of the confinement barriers.

Where fire barriers are penetrated by the confinement system's ventilation ducting, fire dampers shall be appropriately used to maintain the barrier integrity. However, the closure of such dampers shall not compromise the functions of the confinement system where the loss of confinement might pose a greater threat than the spread of fire. In such cases, alternative fire protection means (e.g., duct wrapping) shall be used as a substitute for fire barrier closure. In no case shall a sprinkler system (including safety class sprinklers) be considered a fire barrier substitute.

The following describes an alternative fire protection equivalency approach and full scale test data in assessing the risk of eliminating fire dampers. The objective of the study is to review the references, test data[3] and calculations[4] and describe engineering methods available for horizontal steel ventilation ducts which support the elimination of 39 of 103 fire dampers.

INTRODUCTION

The Defense Waste Processing Facility (DWPF) was built at the Westinghouse Savannah River Site (WSRS) to immobilize the large quantity of high level radioactive waste now stored at the site, plus the waste to be generated from continued chemical reprocessing operations. WSRS is presently the nation's primary source of Tritium, weapon Plutonium, heat source Plutonium, Deuterium, and several other radionuclides for defense, space, medical and energy applications. The plant, which is located near Aiken, South Carolina, comprises a large, remote land area with extensive support facilities and a single operating contractor.

The DWPF Vitrification facility will produce canisters filled with radioactive waste immobilized in borosilicate glass. These canisters will be placed in interim storage until they can be transferred to a federal repository. The long term solution to the nuclear waste problem at WSRS is to remove the waste from waste storage tanks and immobilize the waste in borosilicate glass until it decays. Immobilizing the waste in this manner is more cost effective than continued tank storage and will permit safe transfer of the waste to a federal repository when one becomes available.

FACILITY DESCRIPTION

The main part of the Vitrification Building is a multi-level reinforced concrete structure. It houses the regulated process operations in shielded confinement cells. Because of the intense radiation involved in the vitrification process, most of the operations are conducted in areas shielded by massively thick concrete walls, the canyon. Those fire areas have a ventilation system designed without fire dampers.

The balance of the building houses clean and regulated fire areas enclosed by a combination of rated two hour walls plus unrated massively thick concrete walls. HVAC ducts penetrate those walls. Personnel air locks, Field Operating Stations (FOS), electrical rooms with many cable trays, a railroad well, analytical lab and sampling cells, mercury distillation hood and storage cabinet, clean stairwells, operating and service corridors, and other process support equipment occupy these fire areas.

Nine fire areas are interfaced by the 39 backflow fire dampers. The fire loading, including transient combustible, and hourly fire rating or severity of those fire areas that were calculated for the FSAR are listed here as part of the facility description.

Fire Area		Hourly Rating[5]
5A.4.1	....	0.5 Hours
5A.5.1	....	0.4 Hours
5A.5.4	....	0.5 Hours
5A.5.6	....	0.3 Hours
5A.5.8	....	0.3 Hours
5A.5.9	....	0.2 Hours
5A.6.2A	....	0.2 Hours
5A.6.2B	....	0.2 Hours
5A.7.5C	....	0.2 Hours

VENTILATION SYSTEM

Supply air to the Vitrification Building is delivered by built-up HVAC air supply units. The process areas are divided into three zones for purposes of ventilation and contamination control. The three HVAC zones operate at decreasing pressure differentials from the least to the most radioactive zone which is the major factor in maintaining the integrity of the confinement system.

The HVAC ducts with fire dampers both constructed per SMACNA are installed at penetrations in the massively thick unrated walls and two hour rated walls, but are omitted in the one hour walls in accordance with NFPA 90A. The fire dampers are designed to close automatically when the fusible link is exposed to fire temperatures in order to maintain the integrity of the fire wall. A fire will close a fire damper at an unpredicted time and duration. In addition, NFPA 90A (1989) recommends a trip test of the closing operation of each fire damper bi-annually. In fire damper trip tests, the situation must be considered where there is a trip or reset hang-up which may cause the damper to remain closed for many minutes beyond normal. The closure of a fire damper can cause a backflow which will develop an upset of the HVAC system that can compromise the integrity of the confinement system.

Bechtel performed a fire damper simulation study[6] with the use of the computer model designed for analysis of the DWPF HVAC system operation. The study showed that 39 of 103 fire dampers closed one at a time can cause ventilation system backflow, and consequently compromise the functions of the confinement system. Deletion of those fire dampers will prevent such an upset by maintaining the continuous operation of ventilation system.

HVAC DUCTWORK/DAMPER EQUIVALENCY

Penetrations of two hour fire walls require 1-1/2 hour rated fire dampers per NFPA 90A, Standard for Installation of Air Conditioning and Ventilation Systems. UL 555, Standard for Fire Dampers and Ceiling Dampers[7] specifies operational and performance requirements of fire dampers. The standard requires the ASTM E-119-88[8] furnace test. The fire damper and steel sleeve is secured in the wall with sufficient annular clearance to prevent immobilizing the damper.

The UL 555 acceptance criteria is prevention of flame penetration in the 1-1/2 hour fire test. This means that a duct which remains intact during a fire will prevent flame penetration through the fire barrier. It is even possible under the pass/fail criteria of UL 555 that a duct may be equivalent protection to a fire damper when the connecting duct fails and collapses. This equivalency may follow where a duct without a fire damper stays intact near the wall opening but collapses a distance from the penetration. Radiative and convective heat may transfer through duct and penetration, yet the duct will prevent flame penetration through the fire barrier.

Ducts that remain intact prevent flame penetration at wall openings and inherently equivalent to the NFPA 90A allowance to delete fire dampers in one hour fire rated partitions. Report data[9,10] on steel duct assemblies tested to the standard time-temperature curve ASTM E-119 for one hour is the main basis for the allowance. The test reports identify limitations of the duct work supporting hangers, connecting joints and duct material resulting in warpage of duct walls near the penetration. Large ducts were exposed to a two hour standard fire in a test that included those failure mechanisms.

REVIEW OF A DUCT FIRE ENDURANCE TEST

The report of the duct endurance test performed for the Fire Hazard Analysis at Rocky Flats[11] is used in this study. Three horizontal ducts were tested[11,12], two rectangular 36 X 30 inch 22-gage galvanized steel and one 36 inch diameter stainless steel round duct all constructed per SMACNA[13]. Standard SMACNA hangers and loading was used for one rectangular duct and the round duct.

The second rectangular duct was upgraded with additional support protection consisting of angle reinforcement tack welded two inches from both the inside and outside of the furnace wall to maintain wall rigidity to prevent through openings. Hanger rods were protected with Manville Thermo-12 calcium silicate pipe insulation to increase the fire endurance. An additional trapeze support was installed to increase overall duct support. Reports on that test[12,14] provide details that were omitted in this study for brevity.

At the conclusion of the two hour test which reached 1850°F (1010°C) all duct systems remained in place. There was no significant thermal lag in the exposed duct and hanger rod temperatures as most exposed elements were within 100°F (38°C) of the average furnace temperature. The integrity of each duct system at the fire wall remained intact. No through-openings developed at the penetrations. Longitudinal and transverse duct joints remained tight.[12,14]

None of the ducts failed to prevent flaming through or around the duct penetration. However, the second rectangular duct with added support protection had less warpage of duct walls at the penetration and insulation delayed hanger rod heating.[14]

ENGINEERING METHODS

There are three areas to consider in assessing the risk of eliminating fire dampers. A strict regulatory code approach may lead one to be satisfied, that the equivalency rationale along with the single fire test data,[12,14] will satisfy the fire damper criteria to prevent flame penetration through openings in two-hour walls and partitions. However, wider more general applications of the data is limited or enhanced by:

1. Actual fire loading and peak temperature differences compared to standard test conditions.
2. Correlations between the available single fire test data and the extent of duct loading possible.
3. Fire loading light enough and rigidly controlled so that it will support the elimination of fire dampers directly.

FIRE HAZARD ASSESSMENT

The standard time-temperature curve represents one possible fire situation. Differences among the standard time-temperature curve, fire duration, and peak temperatures that may occur in building fires have been described. Of particular interest are those situations where peak temperatures exceed 1850°F (1010°C), the temperature at the end of the two-hour fire test. Temperature data are also important in assessing the impact of various loading conditions. For the most common situation, ducts located at or near the ceiling, three mechanisms of heating the upper compartment target (duct) can be quantified by correlations developed from compartment fire tests. These include formation of a heated upper layer, direct flame impingement, and heat transfer from a fire plume. The following sections outline methods that can be used to assess fire hazards to steel ductwork.[12]

The DWPF Vitrification Building fire areas are conservatively modeled for a DBF to burn at a fast rate. The fire loading including transient combustibles and consequent hourly rating/severity taken from the Final Safety Analysis Report are 0.5 hours maximum. It is postulated that the light fire loading will be insufficient to attain the widely recognized flashover temperature range of 934°F to 1112°F and calculations[15] confirm this.

The equivalency rationale as suggested by NFPA 90A which allows duct penetrations in one-hour fire walls without fire dampers indicates no impact from direct flame impingement on the ducts and hangers. For the same reasoning, plume impingement would not be an impact on a duct where the fire loading/severity is less than one hour. However, the duct fire test recommendations for enhancing the ductwork structural integrity can provide an additional measure of safety indicated in the basic design document for the DWPF and are included in this study.

Selection of a Design Fire and Application

This important first step assesses the fire hazard for a specific compartment with a quantification of the burning character of the fuels present. The growth rate and peak heat release rate of each fuel are needed.

The first step is to inventory the fuel present in a compartment. For each separate fuel package, the dimensions, weight, surface area, composition, and position should be recorded. Of particular importance is the position of the fuel relative to other fuel packages, walls, and the steel ductwork.

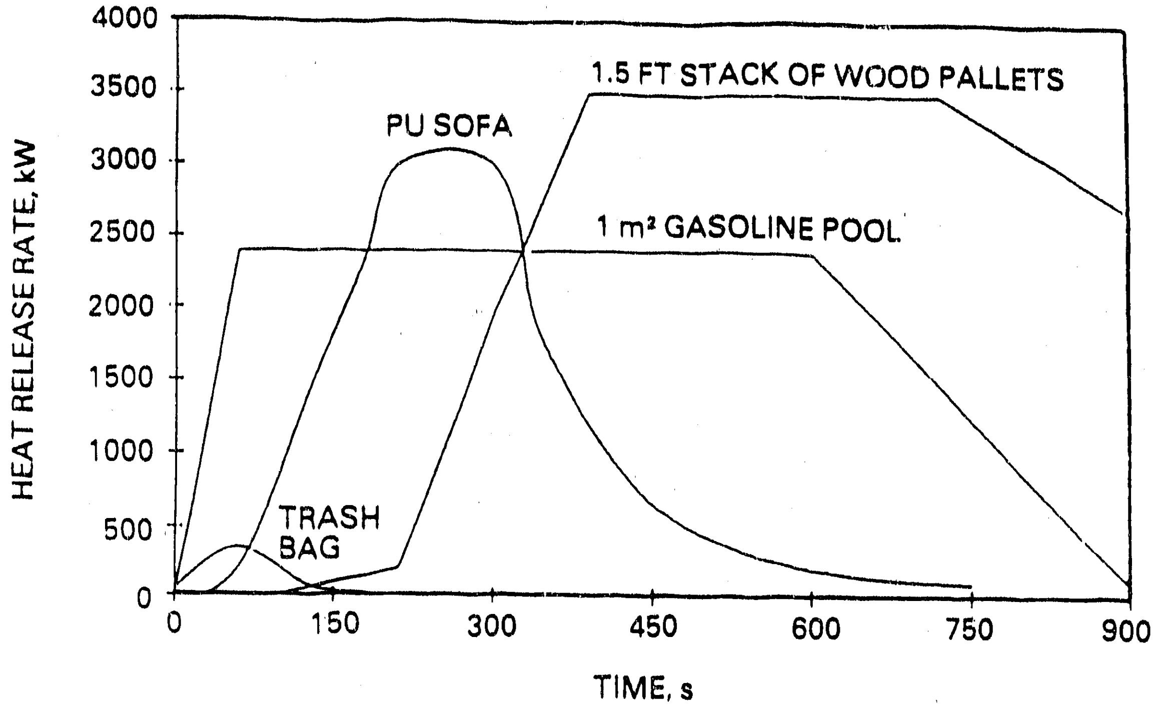

Figure 2: Typical energy release rates for fuel packages.

Having identified the fuel packages and arrangements, the designer must determine combustion data for the major packages. Major packages are those that pose a realistic threat to the ducts. Figure 2 shows typical fuel packages and approximate energy release rates. Engineering judgment may be required to determine realistic fire scenarios. A good approach is to pick cases that will bound the problems so that the effect of design fire selection can be determined. A conservative analysis would include the assumed ignition of the highest growth rate/peak heat release rate package with no interaction of automatic or manual fire suppression systems. Data required for the analysis include the peak heat release per unit area as well as fire growth curves.[14]

Data for common fuels such as storage materials, furniture, or polymers can be found in research reports published by the Building and Fire Research Laboratory (BFRL) of the National Institute of Standards and Technology, Factory Mutual Research Corporation, and other laboratories and testing groups. A good starting point for burning rate data is provided by Babrauskas.[3]

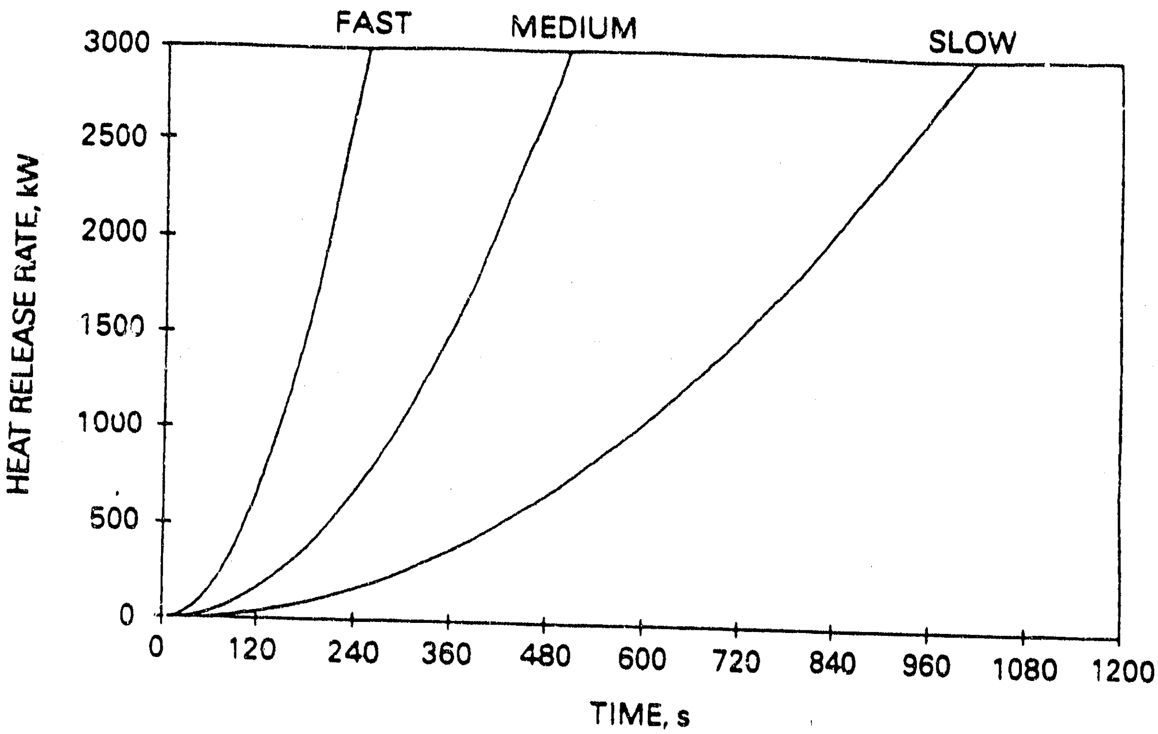

Figure 3: t^2 fire growth rate curves.

Data for fire growth rates are less readily available. An alternative to using specific material test data is to use a power-law fire growth model. Using this approach, the heat release rate is assumed to be proportional to the time squared with a constant of proportionality (at^2). The constant, a, may have a range of values, depending on the time to reach a given heat release rate. For example, in fire detection system design covered under NFPA 72E, the time for the fuel to reach a heat release rate of 1000 BTU/s (1055kW) is used.[16] NFPA 72E has three fire growth classifications: slow, medium, and fast. The time to reach 1000 BTU/s for these classifications are slow, 400 s or more; medium, 150-399 s; and fast, less than 149 s. If this approach is used, the engineer must decide which of these curves, as shown in Figure 3, most closely approximate the anticipated growth rate of each fuel package.

Having determined the fuel heat release and growth rate for the significant fuel packages, the designer must next determine the conditions at the steel ductwork resulting from a fire in a particular fuel package. Three fire mechanisms that may thermally threaten a particular target are direct flame impingement, direct plume impingement, or exposure to a heated upper layer.[14]

Direct Flame Impingement

Impingement by direct flame may occur when the flame is high enough to come in direct contact with a duct located over or near the fuel. The position of the fuel relative to walls and corners is particularly important here. When the fuel is located close to a wall, flames may extend approximately 30% higher than flames from a fire away from enclosure walls.[17] When the fuel is located in a corner, the flame height may be 75% greater. This phenomena occurs as a result of the reduced area available for air entrainment to the flame.

If the flame impinges on the ceiling, it will spread out radially from the point of impingement and form a flame jet. The radius of this flame jet from the point of impingement will be greater than the difference between the unconfined flame height and the fuel to ceiling height. This flame jet may impinge on a target some distance from the base of the fire.

Flame height, $H_f = 1.02D + 0.23Q^{2/5}$ (1)

can be estimated using a correlation by Heskestad[18], knowing the heat release rate, Q, and flam base diameter, D.

Objects that are thermally "thin", such as steel ducts, may be heated rapidly to the flame temperature. Flame temperature is variable but may be in the range of 1740°F to 2010°F (950°C to 1100°C).[19] A thermally "thin" object is one that, when exposed to heat, will heat up quickly and uniformly. Thus, a conservative methodology assumes that, where flames directly impinge on steel duct and hanger assemblies, the steel temperature equals the flame temperature.

Flames may not directly impinge on the duct but may be close enough to receive significant flame radiation. This may result in the same effect as direct flame impingement, except that the heat transfer rate may not be as rapid. If the flame is close to the duct, the radiant flux, q'', may be readily estimated by assuming a view factor, f, of 1.0 and a flame temperature , T_f, of 1100°C (1373°K) using the following equation:

$$\dot{q}'' = f \varepsilon \sigma T_f^4 \qquad (2)$$

where ε = emissivity
σ = Stefan-Boltzmann Constant (5.67×10^{-11} kW/m² K⁴)

A conservative estimate of the emissivity is 1.0, which results in a radiant flux of approximately 200 kW/m². This is a maximum possible radiation and will roughly decrease with the inverse square of the distance from the source to the duct. As this distance increases, the view factor will be less than 1.0 and should be calculated. Once the flux has been estimated, a heat transfer analysis as described in the literature[19] is necessary to determine the resulting duct temperature.[14]

Plume Impingement

If the flame is not tall enough to reach the duct, there is still the possibility that the target may be heated significantly by the plume, which emanates from the flame. The plume will also form a jet at the point of ceiling impingement. This plume jet will spread radially from the point of impingement and may heat ducts some distance away. As an example, the plume jet is largely responsible for the activation of ceiling-mounted heat detectors and sprinklers. The temperature and velocity of the plume jet will decrease with increasing distance from the point of impingement.

To estimate centerline temperatures, T_p, of the plume, the following correlation from Heskestad[18] may be used:

$$T_p = T_a + 9.1\left[\frac{T_a}{gC_p^2\rho_a^2}\right]^{1/3}\dot{Q}^{2/3}(Z - Z_o)^{-5/3} \qquad (3)$$

where T_a = ambient temperature, K

C_p = heat capacity of air, kJ/kgK

= density of air, kg/m^3

Z = height above fuel, m

Z_o = virtual source correction, m

The virtual source correction is used to create a point source height approximation for a fire with a finite area. It is calculated by

$$Z_o = -1.02\,D + 0.083\,\dot{Q}^{2/5} \qquad (4)$$

where $\dot{Q}$ = heat release rate, kW; and D = flame base diameter, m.

Plume temperatures will be significantly less than the flame temperature. However, because of the buoyancy of the plume, it often becomes a significant convective heat source that is capable of rapidly heating immersed objects. The correlations given above apply to the centerline of the plume and are not valid away from the centerline. The plume becomes cooler away from the centerline as a result of ambient air entrainment at the plume boundary. Again, a conservative estimate will result from the assumption that the duct is the same temperature as the plume at the location in question.[14]

Heated Upper Layer

If not heated by direct flame or plume impingement, ducts may be heated by the hot upper layer that forms in a compartment. Buoyant products of combustion will rise to the ceiling and begin filling the compartment from the ceiling down. The rate of the layer descent and temperature of the layer will be dependent on the room size, fire size, and the room ventilation. Two types of ventilation might be considered: natural and forced.

In the case of natural ventilation, air flow to and from the compartment is accomplished by open vents such as doors or windows. The temperature of the upper layer, T_L, assuming it is well mixed and a uniform temperature, is estimated by a correlation developed by McCaffery, Quintiere, and Harkleroad:[21]

$$T_L = T_a + 6.85\left[\frac{\dot{Q}^2}{A_o\sqrt{H_o}h_k A_T}\right]^{1/3} \qquad (5)$$

where A_o = area of opening, m^2
H_o = height of opening, m
h_k = wall heat transfer coefficient, kW/m^2K
= k/δ for $t > t_p$
where k = wall thermal conductivity, kW/mK
δ = wall thickness, m
t_p = thermal penetration time
= $(\rho C_{pw}/k)(\delta/2)^2$

h_k = $(k\,\rho C_{pw}/t)^{1/2}$ for $t \le t_p$
C_{pw} = wall heat capacity, kJ/kgK.

In the case of a compartment with constant and forced ventilation, e.g., from an HVAC system, the correlation developed by Foote, Pagni, and Alvares[22] may be used:

$$T_L = T_a + 0.63\, T_a\left[\frac{\dot{Q}}{\dot{m}C_pT_a}\right]^{0.72}\left[\frac{h_kA_T}{\dot{m}C_p}\right]^{-0.36} \qquad (6)$$

where $\dot{m}$ = ventilation rate, kg/s
A_T = boundary wall area, m^2

This correlation also assumes that the upper layer is well mixed and at a relatively uniform temperature. There are some important restrictions for this correlation related to fire size and ventilation rates. The designer must take into account these limitations as described in Reference 22.

If the duct is attached directly to the ceiling, it will begin heating as soon as the layer begins to form. Ducts located below the ceiling will not be significantly heated until the layer drops to the level of the duct. In the case of suspended steel ducts, the hangers are an important element. Their location with respect to the hot layer must be considered. Estimating the layer level at a given time requires a mass and energy balance of the room, accounting for losses by conduction through the walls, convection through openings, and mass transfer through the openings. One approach is to use a zone model such as ASET[23] or FIRST[24]. These zone models may be used to estimate the upper layer temperature prior to reaching a steady state condition. FIRST may also be used for postflashover analysis.

Upper layer and plume temperatures will be significantly less than flame temperatures. The temperature rise of the target will therefore be slower, and the peak temperature will be less. As a result, the thermal threat from a heated upper layer or plume will be less severe on a local level than flame impingement. The value of these estimating techniques is to provide a thermal threat analysis for situations where duct hangers are loaded to a large percentage of their design strength and to predict the onset of flashover. Where flashover is predicted, one might conservatively assume that all ducts are exposed to the maximum flame temperature. Alternately, postflashover models may be used to estimate the maximum room temperature.[14]

The Vitrification Building cable tray DBF is identified as a fuel controlled forced convection compartment fire with a sufficient oxygen supply. It is assumed that the fire grows to achieve steady state. The temperature is compared against flashover temperatures of 500° C (934° F) to 600° (1112°F). The compartments in the other fire areas also have constant forced ventilation which allows the use of formula (6) to calculate the heated upper layer temperature.

The following is a compilation of the Vitrification Building Fire Areas involved and the calculated (221L11)[15] heated upper hot layer temperature estimates:[11]

Fire Area	Temperature
Level 1 5A.4.1	241°F
Level 2 5A.5.1	554°F
Level 2 5A.5.4	631°F
Level 2 5A.5.6	375°F
Level 2 5A.5.8	412°F
Level 2 5A.5.9	487°F
Level 3 5A.6.2A	374°F
Level 3 5A.6.2B	370°F
Mezz 5A.7.5C	153°F

Flashover is generally defined as the transition from a growing fire to a fully developed fire in which all combustible items in the compartment are involved in fire. During this transition, there are rapid changes in the compartment environment. Flashover is not a precise term, and several variations in definition can be found in the literature. Most have criteria based on the temperature at which the radiation from the hot gases in the compartment will ignite all of the combustible contents. Gas temperatures of 300°C to 650°C have been associated with the onset of flashover although temperatures of 500°C are more widely used. The ignition of unburnt fuel in the hot fire gases, the appearance of flames from openings in a compartment, or the ignition of all of the combustible contents may actually be different phenomenon[5].

The FSAR[5] fire severity for each fire area is based on the ASTM E-119 fire curve[8]. That curve postualtes the combustible load is totally consumed in a short duration at a high temperature. It is assumed in this study that fires in the fire areas being evaluated will follow the EPRI NP-2660 Heat Release Rate curve[20]. If the temperature fails to reach that associated with flashover conditions, it is postulated that fire will fail to breach the fire barrier penetrated by the HVAC duct being evaluated.

DUCT SUPPORT AND LOADING CONSIDERATIONS

The two-hour fire test showed that none of the duct sections failed, and the integrity of each system where it extended through the fire wall remained intact. The longitudinal and transverse duct joints remained tight throughout the two-hour test, preventing flames from entering the duct. No through-flaming was observed where the ducts penetrated the wall. Using UL 555 criteria for fire dampers as a basis for comparison, the three tested duct systems would be deemed to have met the criteria for prevention of flame penetration; in fact, they exceed the criteria because they were exposed an additional one-half hour over that required by NFPA 90A. Not only is the duration longer, but the fire exposure temperature is higher because it continues to increase over that time period. The ducts in the fire test survived a peak temperature of 1850°F (1010°C).

The primary limitation of the fire test data is the difficulty of correlating the results from a single fire test to all possible duct loading conditions. A method described by Jeanes[25] may be used to estimate critical temperatures as a function of loading. This method was developed for evaluating steel structural elements. The approach is based on the reduction of the mechanical properties of the structural material as the temperature is raised. Ultimately, the structural element fails at some critical temperature. The critical temperature is generally defined as the evaluating steel structural elements. The approach is based on the reduction of the mechanical properties of the structural material as the temperature is raised. Ultimately, the structural element fails at some critical temperature. The critical temperature is generally defined as the temperature at which the yield strength of the material is reduced until it nearly equals the design strength, and the factor of safety approaches unity. This approach offers a reasonably simple solution to an otherwise complex problem.

Figure 4 shows steel strength versus temperature. Failure is assumed to occur when the average steel temperature exceeds the temperature on the yield strength curve for a given loading condition or when a single point steel temperature exceeds the temperature on the ultimate strength curve. As an example, average temperatures will be used. Figure 4 shows an example

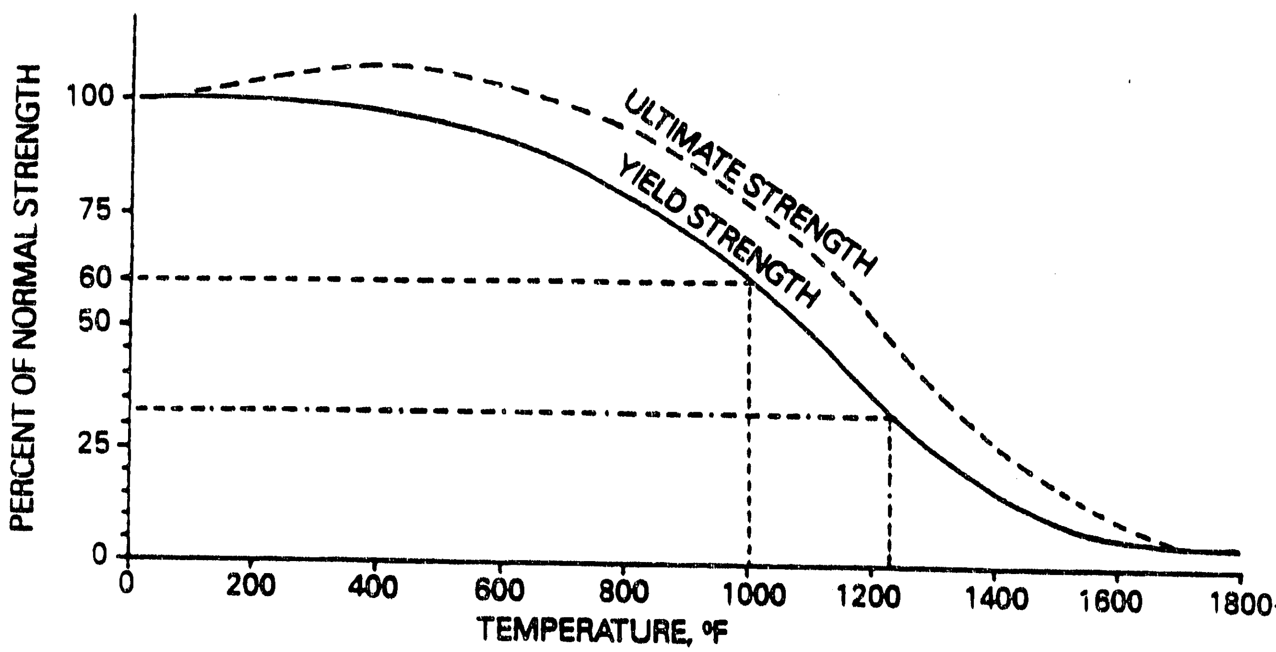

Figure 4: Steel strength versus temperature (from Reference 25).

of a steel element heated to 1000°F (538°C), which reduces its strength to 60% of its normal strength. This is the basis for the ASTM E-119 failure criteria being an average steel temperature of 1000°F (538°C) for a steel column tested without a load, i.e., 60% of the maximum yield strength is normally used as a design working stress. If, in actual conditions, the steel is stressed to only 35% of normal strength, then the average critical temperature is estimated to be 1225°F (663°C).[14]

This estimating technique may be applied to conditions for a specific application. Hanger loading may be calculated in accordance with SMACNA Standards based on duct weight and hanger weight and spacing. Average critical temperature for the hangers may be estimated using Figure 4. Of course, the building structural elements supporting the hangers must be able to withstand the same exposure.[14]

Fire test results show that this technique is conservative in estimating critical temperatures. The critical temperatures for the unprotected rectangular duct loaded to 14% of its design strength are 1425°F (774°C) and 1500°F (815°C) respectively using the estimating technique. The average furnace temperature at the end of the test was 1850°F (1010°C). Following the initial exposure to fire, the rods are assumed to be the same temperature as the furnace atmosphere. Hanger rod temperatures of the unprotected rectangular duct at 120 min. ranged from 1749°F (954°C) to 1805°F (985°C), and the supporting angle temperatures ranged from 1776°F (969°C) to 1874°F (1023°C). The reasons for these conservative results are the safety factor inherent in the estimating technique (e.g., no interaction between elements are considered) and the high safety factor inherent in the maximum loads for the hanger rods allowed by SMACNA. A further indication of this safety factor is the integrity of the duct systems at the conclusion of the test, i.e., the supports still had not failed. The actual critical temperature for these hanger rods is unknown, but for the tested loading conditions, it is greater than a 1850°F (1010°C) exposure temperature and a 1775°F (968°C) average material temperature.[14]

SUMMARY

A framework for evaluating duct opening protection in two-hour fire resistive walls and partitions, previously unavailable, has been described. Key elements of this engineering approach include the following:

1. The rationale for installing fire dampers in HVAC systems:
    a. performance criteria for dampers assumes collapse of surrounding ductwork; and
    b. fire dampers must prevent through-flaming and there are no heat or smoke transmission criteria.

2. Protection equivalent to dampers is provided if ducts stay in place near wall openings and the seal around the penetration is maintained so that there is no through-flaming.

3. Two-hour fire testing of horizontal steel ducts:
    a. ducts designed and constructed in accordance with SMACNA Standards can meet the performance criteria for 1-1/2 hour fire dampers (no through-flaming) when exposed to a standard time-temperature exposure of two hours; and

b. the most important aspects in maintaining duct structural integrity near a wall are:

(1) preventing gaps between the barrier wall opening and the duct;

(2) maintaining the integrity of hanger rods so that ducts are supported near the wall; and

(3) supports for hanger rods to the structure must be able to withstand the fire exposure.

4. Temperature failure criteria for steel duct hanger assemblies may be estimated. These estimates are inherently conservative when compared to actual test data.

5. Temperatures greater than standard furnace test temperatures may result from actual fires. As a result, critical steel temperatures may be exceeded. Engineering tools are available to perform this analysis, which address the following:

a. design fires, including heat release and fire growth rates; and

b. thermal insults resulting from local flame impingement and flashover conditions.[14]

Vertical duct support and loading considerations are difficult to correlate from the single fire test data on horizontal steel ventilation ducts penetrating fire rated walls and partitions. Direct flame impingement and plume impingement on vertical ducts may be similar or less than the impact on horizontal ducts. Here again, a conservative estimate will result from the assumption that the duct temperature is the same as the fire plume adjacent or near the sides of the vertical duct.

Plume impingement and heated upper layer temperatures may have an impact where duct hangers are heavily loaded. The thermal threat from preflashover exposures is less than the two hour E-119 threat.

The study shows that the HVAC ducts tested remained intact during a model DBF and prevented flame penetration of a two hour fire barrier. However, reinforcement of duct work is recommended for identified conditions.

In addition, the fire area where fire dampers are to be deleted in the Vitrification Building develop heated (Hot) layer temperature estimates, calculated under DBF, that are lower than the widely used flashover temperature range of 934°F and 1112°F. The highest estimated temperature 631° occurred in fire area 5A.5.4 of level 2. The RFT shows that DBF pre flashover temperatures do not cause through flaming of a two hour fire barrier.

The Vitrification Building light fire load in fire area 5A.4.1 limited the fire severity to 0.5 hours, the maximum. NFPA 90A allows omission of fire dampers in one hour fire barriers. This equivalency shows that fire dampers may be omitted in accordance with NFPA 90A.

Therefore, the purpose of the study to show that 39 fire dampers may be eliminated while preventing flame penetration of two hour rated fire barriers is achieved.

Based upon the limits of the single fire test an engineering approach to attain a conservative design will evaluate:

1- Vertical HVAC ducts in the fire area for reinforcement or fire wrap.

2- Transient combustibles infusion in the fire loading, as it was for this study.

3- Localized direct flame impingement on the duct.

4- Corner configurations of ducts for reinforcement or fire wrap.

5- Ducts larger than those in the RFT for reinforcement or fire wrap.

6- Use of recommended reinforcing angle stiffeners and pipe insulation on hangers straps and rods on the rectangular duct systems as a precaution.

7- The need for an actual fire (burn) test of the duct configuration at DWPF to substantiate directly that the duct work will remain intact and flame penetration of the two hour fire barrier is prevented in accordance with UL555.

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Mr. Walling began a fire protection engineering career in 1961 with the Factory Mutual Engineering Division upon earning a Bachelor of Science degree in Industrial Engineering at the University of Illinois, Champaign, Illinois.

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