Fire Safety in the Built Environment

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ABSTRACT
Fire safety is the set of practices intended to reduce the destruction caused by fire. Fire safety measures include those that are intended to prevent ignition of an uncontrolled fire, and those that are used to limit the development and effects of a fire after it starts. Designers (architects included) consider every variable associated with the form & function of a building – aesthetics, functionality, cost, environmental sustainability, structural integrity, serviceability and code compliance among a plethora of other variables. There is one variable however that architects do not currently consider so much and yet it has the ability to fundamentally, and often negatively, alter the design of a building: ***Fire safety****. This write up attempts to investigate facts that Architects do read fire codes and fire safety engineers do work closely with architects to design fire safe buildings, but for some reasons we still end up with an ill-informed, un-coupled approach to fire safety and a design resulting from this process will by definition never be fully optimized. There was a realization that this system could be improved with proper fire safety design measures from planning stage to orientation of buildings, fire safe landscaping, passive and active fire prevention methods in such a way that the safety of the users of building is assured against fire out-breaks.*

Keywords: *Fire Safety, Design, and Building*

INTRODUCTION

In ancient times people were not conscious about the hazards of the fire break out in the buildings and as such old constructions were not planned and constructed by considering this aspect. With the new advancements and also due to increase in population space for constructing the buildings is reduced day by day. Today in big cities it is tried to construct more and more houses and other structures for economic use on the limited available space. To accommodate more and more people in less and less restricted area, constructions are done multistoried. This leads to the concentration of large population in a very small restricted area which in turn causes so many problems of traffic, sanitation, drainage, health etc. In such a thick populated area if fire out-breaks occurs in one building it may engulf so many adjacent buildings and loss due to fire outbreak may be enormous. Due to electric fittings in buildings, chances of fire have also greatly increased. So chances of fire out-break have increased manifold and as such in all the constructions carried out today, protection from fire is kept in view. Today architects and engineers, design, plan, and orient the buildings in such a way that the safety of the users of building is assured against fire out-breaks.

The word fire proofing is actually misnomer, as there is no material especially amongst the building materials, which could be considered fully fire proof. All that can be done is to make building fire resisting within reasonable limits by adopting such materials in construction that are comparatively more resistant to fire. By adopting some specific measures, the effect of fire, in case of fire out-break, can be considerably delayed so as to enable the occupants to move to safer places. The international fire prevention congress in 1903 recommended the use of term 'fire resists resisting' in the place of 'fire proofing' as fire proofing of the buildings is neither possible nor required. Following facts should be remembered while designing a fire resisting building:

1. It is very costly to render all the buildings fully protected against fire. Actually, the amount spent for making the structure fire resisting should be related to the loss that may occur in case of fire.
2. It is not always true that non-combustible materials possess more power to resist fire. For example a timber section is better fire resistant than an unprotected rolled steel joist.
3. The object of making a building fire-resistant is to protect the life, goods, and activities within the building. Life is most precious which must be protected at all costs. In case of fire outbreak damage is bound to occur, both to goods lying inside the building and to the building itself. The buildings which have been treated against fire to cause less damage.
4. The degree of fire resistance required, actually depends on the use of building. For instance town halls, cinemas, terminals, theatres, require greater degree of fire resistance than a ware-house.
5. In case of fire, danger comes from smoke, fire and panic. Suitable provisions should be made in the buildings so as to escape from fire as soon as possible. Provisions of escape should be indirect, relation to the number of persons likely to be affected and should be located in such a way that they remain unobstructed by smoke or fumes. Danger from panic is greater when a larger number of people are trapped in a confined area.

PRINCIPLES OF FIRE BEHAVIOR

The "Fire Triangle:" This is a simplified figure below that describes fire in terms of its three essential elements; if one is absent or removed, combustion will not occur: Oxygen must be at least 16% of the atmosphere to sustain combustion. If oxygen is consumed by fire and drops below this level, combustion ceases. Fuel (solid, liquid, or gaseous) must be present in sufficient concentration to form combustible mixture with oxygen. Liquid and solid fuels must be pre-heated to temperatures at which they give off combustible gases. If the fuel supply is consumed, separated, or removed, combustion will cease. Heat must be sufficient to produce and ignite combustible gases; solid and liquid fuels must be pre-heated to distill these gases before they will ignite.

Fuels kept or cooled below their ignition temperatures will not support combustion. A fire will also self-terminate if burning fuels do not produce adequate heat to ignite fire gases or distill new fire gases from liquid and solid fuels.

STAGES OF FIRE DEVELOPMENT:

If left unattended, fires evolve through several predictable stages: Pre-burning occurs when fuel is exposed to the heat of an ignition source, leading to the distillation of combustible gases. Other than the original ignition source, no flame is visible and temperatures are not markedly elevated. Initial burning involves progress of a fire from the ignition of volatile fire gases to the production of sufficient heat to sustain the combustion process. At this point, flame height is approximately 10 in. (25 cm) and ceiling temperatures range from normal room temperature to 250F.

Vigorous burning is the phase during which a fire advances from marginal self-sustained combustion to spreading across the fuel surface. Flame height is from 10 in. (25 cm) to 5 ft. (1.5 m) high, ceiling temperature from 250F to 600F. The fire begins to have an effect on the ignition of surrounding materials. Interactive burning occurs as fire makes the transition from full involvement of items and fuel packages to full involvement of whole rooms. Flame height is from 5 ft. (1.5m) to full contact with the ceiling and horizontally beyond; ceiling temperatures range from 600F to 1400F. The heat radiated by the burning of one fuel package speeds the combustion of another, causing an exponential growth in fire intensity. Remote burning occurs as fire makes the transition from involving entire rooms to rapidly consuming large sections of entire building. Horizontal flame spread at the ceiling would extend dozens of feet along open channels. Ambient temperatures would reach 1200F to 1500F.

PASSIVE FIRE PROTECTION

Passive Fire Protection (PFP) is an integral component of the three components of structural fire protection and fire safety in a building. PFP attempts to contain fires or slow the spread, through use of fire-resistant walls, floors, and doors (amongst other examples). PFP systems must comply with the associated Listing and approval use and compliance in order to provide the effectiveness expected by building codes.

ACTIVE FIRE PROTECTION

Active Fire Protection (AFP) is an integral part of fire protection. AFP is characterized by items and/or systems, which require a certain amount of motion and response in order to work, contrary to passive fire protection.

FIRE-SAFETY DESIGN PRINCIPLES

GENERAL PRINCIPLES

Every fire is somewhat unique. Still, design professionals can do a great deal to enhance their background in fire safety by knowing useful generalizations concerning the requirements of fire-safe buildings. Consider the following:

- Fire safety planning should be based on knowledge of general fire behavior, fire behavior in buildings and building behavior under fire conditions.
- Structural fire resistance is a prerequisite to other considerations of occupant fire safety.
- Building contents, their selection and organization, must be recognized as a key influence on fire safety in buildings.
- Integrated fire protection should be a planning consideration in every building project.
- Redundant fire protection (*i.e.*, back-up provisions for key systems) should be part of an effective design.
- Worst case "possibilities" should parallel "probabilities" as planning tools in developing fire-safe designs.

Code compliance: This an indispensable part of effective fire-safety designs. Building and life safety codes define the architect's minimum legal responsibilities for protecting building users from fire. Their provisions provide a useful framework for expanding the designer's general knowledge of general fire safety issues:

- Occupancy classification: The unique fire safety requirements of buildings based on the type of activity they accommodate.
- Configuration: The fire safety implications of buildings in context, including setback requirements, site access, *etc*.
- Egress and evacuation: Requirements for leaving all spaces and moving safely through the building.
- Exterior protection: From exterior fires, including adjacent buildings, wild lands, *etc*.
- Interior protection: Required to maintain structural stability.
- Internal separation: For various occupancies and functions.
- Mechanical requirements: To support fire prevention and control and to protect occupants and property.

FIRE SAFETY DECISION TREES

These provide a valuable tool for defining and managing fire-safe design objectives. Two particularly useful conceptual models have been developed for use by architectural and design professionals. In general, both address three major fire safety goals:

Prevent ignition of building materials and contents
Regulate ignition sources
Control fuel
Control heat/fuel interaction
Plan for occupant action

CONTROL FIRE DEVELOPMENT

Detect fire.
Control combustion.
Suppress/extinguish fire.
Limit spread.

PROTECT THE EXPOSED BUILDING OCCUPANTS.

Communicate emergency information.
Provide for emergency egress.
Defence in place.

PREVENT IGNITION
REGULATE IGNITION SOURCES

The probability of fire ignition can be substantially reduced by regulating building features and contents that produce sufficient heat to ignite adjacent materials. Ignition sources that cannot be eliminated should be separated from possible fuels. Consider:-
Open flames and glowing combustion: fireplaces, pilot lights, industrial
processes, smoldering cigarettes.
Chemical heat: chemical reactions, oily rags, solvents, decomposition of organic materials,
Resistance heating: electric space heaters and heating coils, overtaxed electrical wiring.
Electrical arcing: electric shorts, poor electrical connections, poorly maintained equipment.
Static electricity: excessive dryness energized electrical equipment.
Friction heating: faulty bearings or metal-to-metal contact between moving parts.

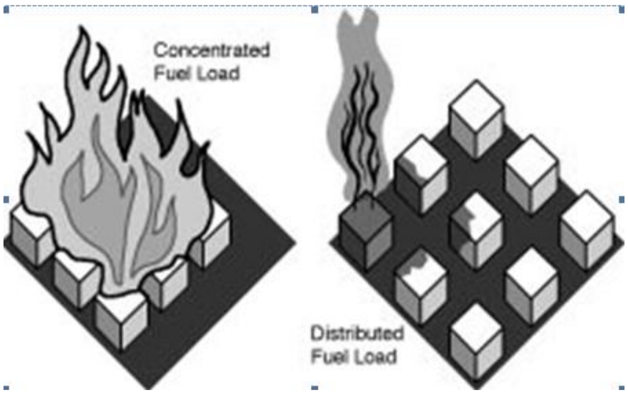
FIRE SAFETY OBJECTIVES
CONTROL FUEL

The risk of fire ignition can be reduced by regulating selected fuel characteristics. Especially in routes of egress, areas of having high occupant loads, and other high risk areas, materials should be carefully selected with regard to:
- Volatility: the ease with which a material gives off flammable gases; many “flammable liquids,” such as gasoline, give off flammable vapors at well below normal room temperatures.
- Ignition temperature: the temperature at which a material will ignite; the higher a material’s ignition temperature the longer ignition will be delayed.
- Thermal inertia: the tendency for a fuel to absorb and disperse the heat of ignition, rather than allowing heat to saturate one area and ignite.
- Surface to mass ratio: fuel surface exposed per unit of mass; more finely divided fuels expose more mass to heat, reach ignition temperatures more quickly, and burn more rapidly.
- Fuel orientation: the more of a material exposed to an ignition source, the more rapidly thermal inertia will be overcome and the material ignited.
- Surface texture or roughness: increases the exposed area of a surface, increasing the amount of material progressing toward ignition at any one time.

CONTROL HEAT/FUEL INTERACTION

Even in the presence of potential ignition sources and volatile fuels, ignition can be prevented by maintaining adequate separation between the two. Such planning should address the three primary means of heat transfer between areas:

- *Convection* is heat spread via a "fluid" (usually air). The buoyancy of heated air (its tendency to rise) is a major influence on fire spread. Spread is also influenced by pressure build-up in closed spaces and direct flame impingement on adjacent materials.
- *Conduction* is the transfer of heat along highly thermally conductive materials to fuel packages that are in contact with them.
- *Radiation* is heat transfer via electro-magnetic waves, along lines of sight, such as radio waves, sound, and light. If sight is blocked, heat is blocked. Each of these three means should be considered in detail, as follows:
- Concentrated fuel: the smaller the space in which a given quantity of fuel is loaded the more likely it is to give off its heat in a short period of time.



Separation may take the form of physical barriers or spatial distance. Plan to separate fuel.

PLANS FOR USERS ACTION

Although user actions are not under design control, fire preventive behaviors can be encouraged by providing them with relevant information. Such actions might also include local officials and fire fighters.
- Building-use manuals can include guidelines for preventing ignition, making reference to possible ignition sources (*e.g.*, manufacturing equipment), probable fuel concentrations (*e.g.*, storage rooms, work areas), and possible ignition scenarios.
- In-house fire prevention checklists, addressing a variety of housekeeping and related fire safety issues, can be a standard document for distribution to clients.
- Anticipate unsafe behaviors: Parallel user fire prevention measures with focused safeguards in areas where complexity and human nature pose increased risks of fire ignition:
- Increase physical separation of fuel and ignition sources in such areas.
- Strengthen general security measures in areas where a threat of malicious or opportunistic fire-setting exists.
- Disconnection and complete removal of all electrical appliances for the sockets. The neutral line of supply still carries some bit of current which in case of lighting or flash from high tension lines, current could still flow through appliances even when switched off but not disconnected from the socket. Below is an example of the effect of flash light from high tension line through the satellite LNB (low noise block) into the electrical appliances causing fire that destroyed all appliances linked to the satellite and also burnt part of the ceiling of the property.

Source: Author

In this case, even though, the occupants switched off all sockets but they forgot to disconnect they appliances from the sockets, as such there was a flow of current and it resulted to fire spread.

CONTROL FIRE DEVELOPMENT

DETECT FIRE

Automatic Fire Detection takes a variety of specialized forms and variations. The most common include:

Heat detectors activate in the presence of hot smoke and gases.

- "Fixed temperature" types activate at preset temperatures.
- "Rate of rise" types detect unusually rapid temperature change.
- "Rate compensation" detectors combine characteristics of the two above.

Smoke detectors activate in the presence of solid particles or droplets produced by a fire.

- "Ionization" types activate when smoke (especially when made up of small particles produced by fast, hot fires) causes a change in the electrical charge inside the detector.
- "Spot-type photoelectric" detectors activate when smoke (particularly large particles produced by smoldering fires) break up light internally.
- "Projected-beam photoelectric" detectors activate when smoke (particularly large particles) break an "electric eye."
- "Sampling" detectors collect and analyze smoke in a small, closed chamber.

Supervised extinguishing systems, such as automatic sprinkler systems, incorporate detection as part of their operating systems. When the system is activated, an alarm also sounds.

Flame detectors, especially useful where volatile fuels are present, detect infrared, ultraviolet, and other wavelengths of radiant energy produced by combustion.

Detector placement should be considered in the following locations:

- At required intervals stated in applicable codes and standards.
- Near anticipated hazards, to provide timely detection.

- Clear of nuisance sources (general cooking odours, dust sources, shower rooms, *etc.*) to minimize false alarms.
- At regular intervals throughout a space for even coverage.
- In accessible areas to facilitate testing and maintenance.
- Away from dead air pockets, where arrival and detection of fire products may be delayed.

Notification systems take a variety of forms:

- General alarm notification throughout a building is required for many types of occupancies.
- Zoned notification allows alerting of occupants in most affected areas of a large building first, to enable building evacuation on a priority basis.
- Pre-signal notification sounds an alert at a staffed station, giving staff time to investigate and correct situations before automatically sounding a general alarm.

Occupant detection and notification should include facilitation of occupant reporting with:

- Manual pull stations at intervals along exit routes.
- Emergency phones directly connected to alarm centers.
- Public phones, highly visible, outside exit routes.

CONTROL COMBUSTION

Room geometry influences the upward and outward movement of fire through space, a pattern called "mushrooming." Heat rises until it encounters a horizontal barrier, then moves horizontally. Horizontal spread continues until the fire front can move upward along a new vertical path or strikes a vertical barrier and is forced downward by rising fire gases behind it. Several variables are important:

- Compartment height: The higher the ceiling, the more room air a plume of hot gases passes through before it contacts the building.

High ceilings also provide more dilution of heat with fresh air and cool the fire gases before they reach the ceiling.

- Floor area: Ceiling height being equal, the room with the largest floor area distributes fire over the largest ceiling area (cooling it more quickly in the early stages), delaying its "mushrooming" down the walls to furnishings and contents on the floor.
- Volumetric configuration: Determines the route of heat and fire products within and along room boundaries. Flat ceilings tend to distribute heat equally in all directions; mono-pitched ceilings concentrate heat along their upper edge; pyramidal ceilings concentrate heat intensity at their peak, resulting in more rapid burn-through. Fuel characteristics should be appropriately regulated with regard to fire spread, giving special attention to areas with increased probability of ignition, increased life hazard, special safety significance (egress routes, refuge areas, *etc.*) or to areas of particularly high value. Evaluate materials in terms of:
- Ignition temperature: the temperature at which a material will ignite; the higher a material's ignition temperature the longer ignition will be delayed.
- Flame spread: the speed with which fire spreads across a surface; review test results such as ASTM E-84 (Class A, 0-25 flame spread; Class B, 25-75; Class C, 75-250); the higher the flame spread rating, the more hazardous the material.
- Fuel contribution: the quantity of heat released by a material (in BTUs/pound) during combustion.
- Surface to mass ratio: affects probability and rate of combustion.
- Concentrated fuel "packages:" tight clusters or arrangements of fuel focus their heat release on a small area when burned; concentrated fuel results in more rapid ignition of surrounding materials than uniformly distributed fuel.

- High placement of fuels: exposes them to higher temperatures near the ceiling, resulting in more rapid ignition.
- "Chimney" configurations: placement of fuels near walls or other fuels to form vertical void spaces; heat rising through these "chimneys" radiates from one side to the other, causing more rapid preheating, air flow and burning.
- Vertical orientation of fuels: (drapery, tapestries, partitions) exposes upper surfaces to pre-heating by material burning below, resulting in exponentially rapid fire growth

SUPPRESS/EXTINGUISH FIRE

Manual occupant suppression—the ability of occupants to put out a fire—early in a fire is the best chance of controlling active fires with the least threat to life and property. For this reason, buildings most often include provision for occupant-use extinguishing equipment, such as hose cabinets, manual suppression system activation, and various types of portable fire extinguishers:

Manual fire department suppression—the ability of trained fire fighters to control and extinguish a fire—can be aided through building design with a number of positive contributions to the response, capability and reliability of manual fire department suppression efforts:

Early notification affords the best chance of effective fire department suppression, since fires develop exponentially over time.

Rapid notification systems take several forms:

– Auxiliary alarm systems connect directly to the municipal fire department dispatch center.
– Central station systems route alarms through a private alarm office which relays them to the fire department.
– Proprietary systems are staffed by on-site employees who receive and relay alarm information to fire department.

Site access can be improved by eliminating impediments to safe, efficient emergency operations:

– Hydrants that are highly visible and accessible
– Site features, including driveways, parking, pedestrian facilities, plantings and other landscaping, that provide unimpeded movement around the building.

AUTOMATIC SPRINKLER SUPPRESSION SYSTEMS

These systems act immediately (even in unoccupied areas), exactly where they are needed, using a minimum of extinguishing agent. A well-designed and maintained automatic suppression system is faster, more efficient, and less likely to do additional damage than manual fire department suppression. All types of automatic sprinkler systems use pre-piped waterways and regularly spaced sprinkler heads individually activated by fire contact. Sprinkler systems can be specialized in a variety of ways including large-drop systems for use in atrium and other high ceiling spaces, several quick-acting technologies, heads that are "hidden" from sight, *etc*.

LIMIT SPREAD AREA

Compartmentation is a critical part of fire control. It involves the division of a building into separate fire areas, each separated from others by a perimeter of fire resistive "barriers."

Openings in barriers must be equipped with either self-closing devices that close them immediately after use, or automatic closers that close the assembly when fire is detected. Each piece of equipment inserted in a fire resistive barrier must be equipped with an individually rated assembly, of appropriate fire resistance, to close it off during a fire. In finalizing barrier details, attention should be given to specification of:

- Walls.
- Ceilings and floors.
- Separation of occupied and concealed spaces.
- Vertical barriers to spread between floors.
- Doors.
- HVAC equipment, such as ducts, transfer grilles, *etc.*
- Service openings, such as hose cabinets, access panels, and hatches.
- Lighting equipment.
- Poke-through for electrical, plumbing, and other utilities.

Thermal resistance is important in barriers to ensure they do not spread heat to adjacent areas by conduction. Building codes specify minimum hourly fire-resistance requirements for barriers in various occupancies and minimum thickness requirements for various insulating materials to meet these requirements.

Inherent structural stability under fire conditions is partially dependent on a structural system's inherent performance under fire conditions. Factors affecting the strength include:

- Materials used and their unique fire resistive properties
- Alteration or changes in original properties or use.
- Physical condition: decay, rust, cracking, *etc.*
- Loading (static and anticipated dynamic loadings) and safety factor.
- Exposed surface area: the greater the exposed surface, the more rapid the effects of heat exposure.
- Height or span of structural components.
- Method(s) of connection.

Structural fire protection is required. Despite their inherent resistance to fire, most structural systems need some sort of supplementary protection from fire. Common methods include

- Encasement of structural components inside close-fitting, fire resistive cladding.
- Coating of components with insulating materials.
- Membrane protection, such as suspended ceilings, which separates structural components from fire exposure by distance.

– Key boxes, convenient alarm panels, and legible plan depiction to speed access to interior fire areas.

– Walk-through inspections with fire officials are helpful to firefighters and to building operators.

Fire suppression support should be free of impediments to safe, efficient emergency operations:

– Standpipe systems inside fire resistive enclosures and easily accessible from major access points.

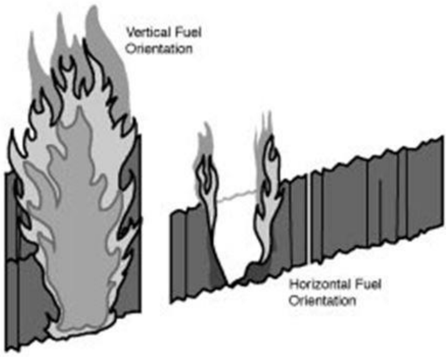
– Elevators that provide complete manual operation by emergency crews.

– Integrated building communications system (conventional radios are often ineffective in steel-frame and reinforced concrete buildings).

Ventilation, the removal of smoke and hot fire gases, allows emergency crews to protect occupants, work under safer, more efficient conditions, and isolate fire to smaller areas. Common building ventilation methods include:

– Rooftop gravity vents that exhaust heat directly outside.

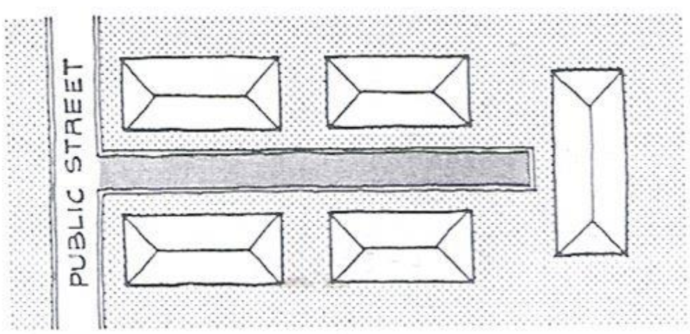
– Engineered smoke-removal systems sometimes allow pressurization of fire floor(s) to prevent spread to uninvolved areas.



LANDSCAPE CONSIDERATION IN FIRE SAFETY
DRIVE LAYOUTS
To provide for ease in maneuvering avoid long (greater than 150ft), narrow drive ways that do have adequate turnarounds. Dead ends should be avoided. Shown below are examples of drive way layout present in order of increased provisions for ease of fire apparatus maneuvers.

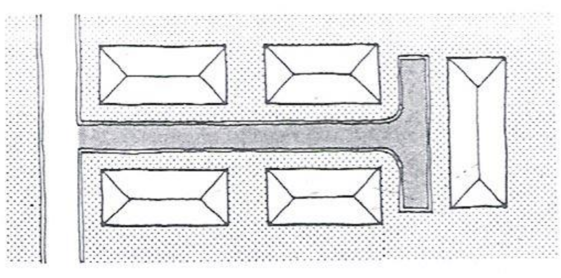
DEAD END

Can cause time consuming, difficult back-up maneuvers



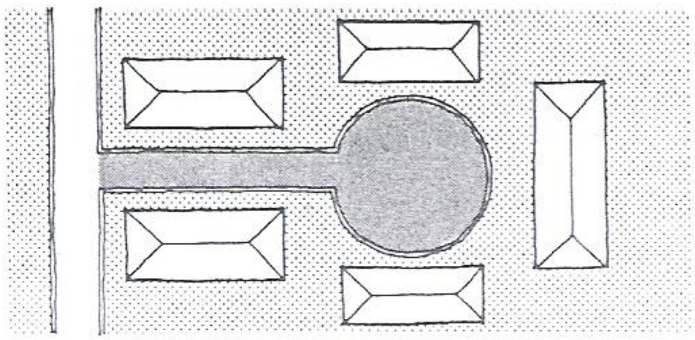
T-TURN OR HUMMER HEAD

Provide means to maneuver and change direction without length back-up maneuvers.

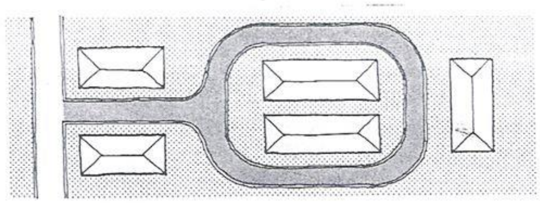


CUL-DE-SAC

Clear turning radius should be at least 40ft



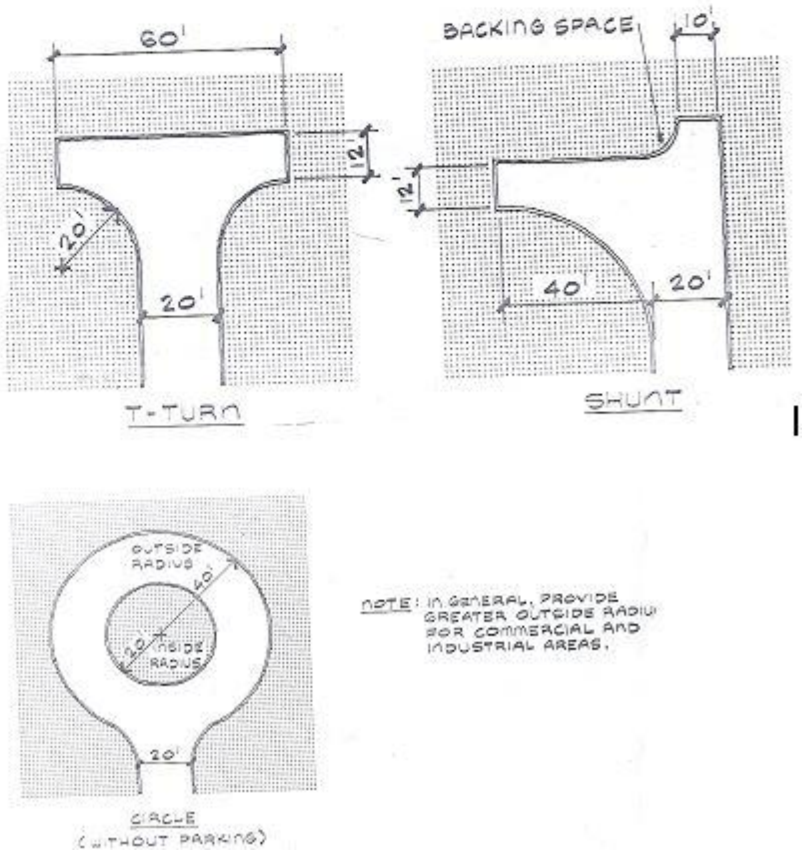
CURVED DRIVE WAY



Source: ***M. David Egan (1978) concepts in building fire safety***

TURNAROUNDS

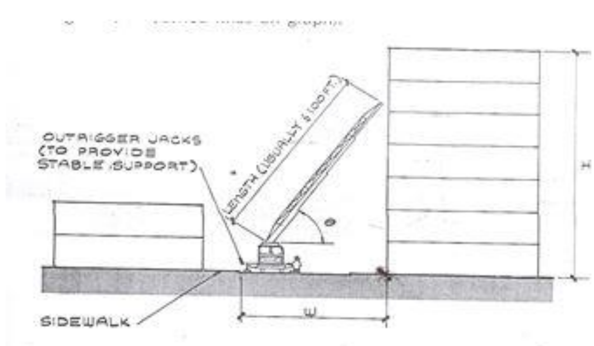
Turning space for fire apparatus should be provided at dead ends to avoid dangerous back up maneuvers. Shown below are example turnarounds that allow expeditious changes of direction. Parking should not be permitted in T-turns or shunts. The examples are given for a road width of 20ft, the generally accepted minimum width for a two–way minor road without parking.



Source: ***M. David Egan (1978) concepts in building fire safety***

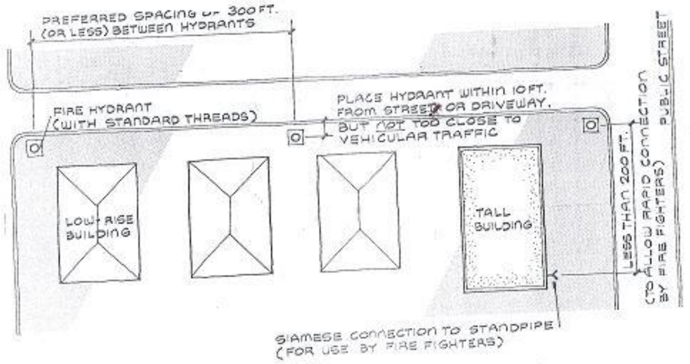
DRIVEWAY WIDTH FOR AERIAL APPARATUS.

To allow full extension of aerial ladders at a safe climbing or elevation angle of 60 to 80 degrees, sufficient space is needed to position (or "spot") the apparatus. The graph below shows typical width (*W*) in feet to allow operational space in driveways to reach buildings of various heights (*H*) in feet. For example, to reach the roof of at least 24ft is needed for a preferred elevation angle of 70 degrees (see dashed lines on graph).



FIRE HYDRANT LAYOUTS

Shown below is an example layout for fire hydrants serving a row of dwelling units. Locate hydrants at street intersections and at midpoints along streets where the distance between intersections exceeds 400ft. the need for long fire hose lines will cause delay and will require high water pressure from fire apparatus pumps, do not place hydrants with 50ft of buildings, unless the construction is fire resistive or the facing wall is masonry without openings. For remote site locations, be sure that hydrant is not further than 300ft away from the buildings to be protected.



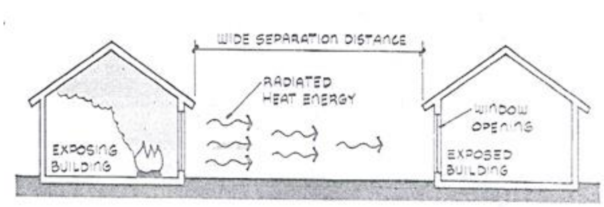
Source: ***M. David Egan (1978) concepts in building fire safety***

METHODS OF EXPOSURE PROTECTION

Buildings located near a burning building are exposed to radiant and convected heat energy. Radiated heat energy can be reduced by (1) increasing the separation distance (2) using outside sprinklers, (3) self –supporting barrier walls, and (4) decreasing (or eliminating) the area of wall openings. Example methods of exposure protection are shown below

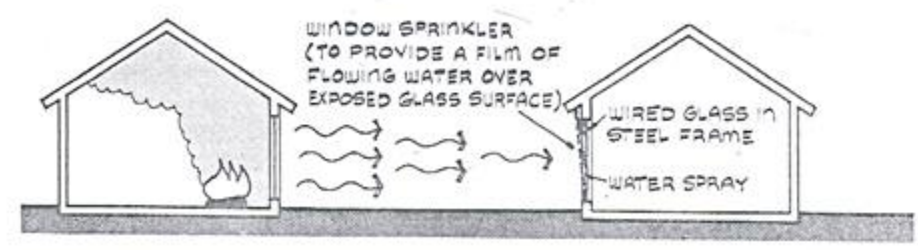
SEPARATION DISTANCE

Depends on fire hazard, site characteristics, and the like,



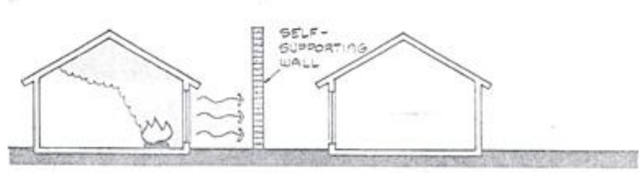
OUTSIDE SPRINKLERS

Prevent ignition of a building’s exterior surfaces, interior finishers, and contents.

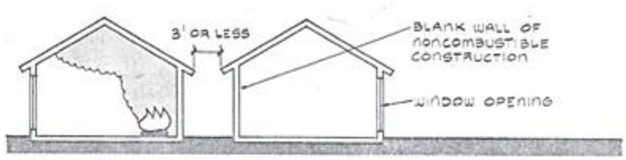


BARRIERS

Concreter brick, or block walls shield adjacent buildings



NO OPENINGS



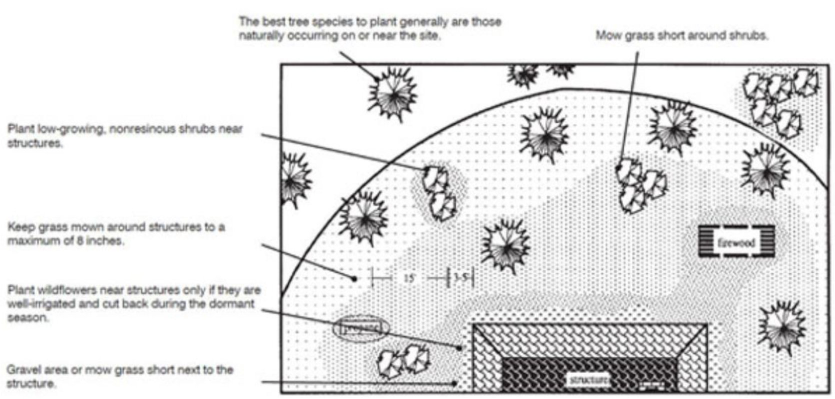
Source: ***M. David Egan (1978) concepts in building fire safety***

Improper landscaping worries land managers and fire officials because it can greatly increase the risk of structure and property damage from fire. Vegetative clearance around the house (defensible space) is a primary determinant of a home's ability to survive wildfire. Defensible space is, simply, room for firefighters to do their job. If grasses, brush, trees and other common fire fuels are removed, reduced, or modified to lessen a fire's intensity and keep it away from the home, chances increase that the structure will survive. It is a little-known fact that in the absence of a defensible space, firefighters will often bypass a house, choosing to make their stand at a home where their safety is more assured and the chance to successfully protect the structure is greater.

LANDSCAPING DEFENSIBLE SPACE

People often resist creating defensible space because they believe that it will be unattractive, unnatural and sterile-looking. It doesn't have to be! Wise landowners carefully plan landscaping within the defensible space. This effort yields a many-fold return of beauty, enjoyment and added property value. Many plant species are suitable for landscaping in defensible space. Use restraint and common sense, and pay attention to plant arrangement and maintenance. It has often been said that how and where you plant are more important than what you plant. While this is indeed true, given a choice among plants, choose those that are more resistant to wildfire. Consider the following factors when planning, designing and planting the Fire Wise landscape within your home's defensible space:

- Landscape according to the recommended defensible-space zones. That is, the plants near your home should be more widely spaced and lower growing than those farther away.
- Do not plant in large masses. Instead, plant in small, irregular clusters or islands.
- Use decorative rock, gravel and stepping stone pathways to break up the continuity of the vegetation and fuels. This can modify fire behavior and slow the spread of fire across the property.
- Incorporate a diversity of plant types and species in your landscape. Not only will this be visually satisfying, but it should help keep pests and diseases from causing problems within the whole landscape.
- In the event of drought and water rationing, prioritize plants to be saved. Provide available supplemental water to plants closest to your house.
- Use mulches to conserve moisture and reduce weed growth. Mulch can be organic or inorganic. Do not use pine bark, thick layers of pine needles or other mulches that readily carry fire.
- Be creative! Further vary your landscape by including bulbs, Garden art and containers for added color.



Source: http://www.ext.colostate.edu/pubs/natres/06303.html

GRASSES

During much of the year, grasses ignite easily and burn rapidly. Tall grass will quickly carry fire to your house. Mow grasses low in the inner zones of the defensible space. Keep them short closest to the house and gradually increase height outward from the house, to a maximum of 8 inches. Maintenance of the grassy areas around your home is critical. Mow grasses low around the garage, outbuildings, decks, firewood piles, propane tanks, shrubs, and specimen trees with low-growing branches.

GROUND COVER PLANTS

Replace bare, weedy or unsightly patches near your home with ground covers, rock Gardens, vegetable Gardens and mulches. Ground cover plants are a good alternative to grass for parts of your defensible space. They break up the monotony of grass and enhance the beauty of your landscape. They provide a variety of textures and color and help reduce soil erosion. Consider ground cover plants for areas where access for mowing or other maintenance is difficult, on steep slopes and on hot, dry exposures.

Ground cover plants are usually low growing. They are succulent or have other Fire-Wise characteristics that make them useful, functional and attractive. When planted in beds surrounded by walkways and paths, in raised beds or as part of a rock Garden, they become an effective barrier to fire spread. The ideal groundcover plant is one which will spread, forming a dense mat of roots and foliage that reduces soil erosion and excludes weeds.Mulch helps control erosion, conserve moisture and reduce weed growth. It can be organic (compost, leaf mold, bark chips, shredded leaves) or it can be inorganic (gravel, rock, decomposing granite). When using organic mulches, use just enough to reduce weed and grass growth. Avoid thick layers. When exposed to fire, they tend to smolder and are difficult to extinguish. Likewise, while your property might yield an abundance of needles from your native pines or other conifers, don't use them as mulch because they can readily catch and spread wildfire. Rake, gather and dispose of them often within your defensible space.

SHRUBS

Shrubs lend color and variety to the landscape and provide cover and food for wildlife. However, shrubs concern fire professionals because, as the next level in the "fuel continuum," they can add significantly to total fuel loading. Because of the woody material in their stems and branches, they are a potential source of fire brands. When carried in the smoke column ahead of the main fire, fire brands can rapidly spread the fire in a phenomenon known as "spotting."

But the primary concern with shrubs is that they are a "ladder fuel" -- they can carry a relatively easy-to-control surface grass fire into tree crowns. Crown fires are difficult, sometimes impossible, to control.

To reduce the fire-spreading potential of shrubs, plant only widely separated low-growing, non-resinous varieties close to structures. Do not plant them directly beneath windows or vents or where they might spread under wooden decks. Do not plant shrubs under tree crowns or use them to screen propane tanks, firewood piles or other flammable materials. Plant shrubs individually, as specimens, or in small clumps apart from each other and away from any trees within the defensible space.

Mow grasses low around shrubs. Prune dead stems from shrubs annually. Remove the lower branches and suckers from species to raise the canopy away from possible surface fires.

TREES

Trees provide a large amount of available fuel for a fire and can be a significant source of fire brands if they do burn. Radiant heat from burning trees can ignite nearby shrubs, trees and structures. The best species to plant generally are those already growing on or near the site. Others may be planted with careful selection and common sense.

If your site receives enough moisture to grow them plant deciduous trees. These species, even when planted in dense pattern, generally do not burn well, if at all. The greatest problem with these trees is the accumulation of dead leaves in the fall. Remove accumulations close to structures as soon as possible after leaf drop.

When site or available moisture limits recommended species to evergreens, carefully plan their placement. Do not plant trees near structures. Leave plenty of room between trees to allow for their growth. Spacing within the defensible space should be at least 10 feet (3 meters) between the edges of tree crowns. On steep ground, allow even more space between crowns. Plant smaller trees initially on a 20- to 25-foot (6-8 meter) spacing to allow for tree growth. At some point, you will have to thin your trees to retain proper spacing. As the trees grow, prune branches to a height of 10 feet (3 Meters) above the ground. Do not over prune the crowns. A good rule of thumb is to remove no more than one-third of the live crown of the tree when pruning. Prune existing trees as well as ones you planted.

STRUCTURAL ELEMENTS OF A FIRE SAFE LANDSCAPE

When building a deck or patio, use concrete, flagstone or rock instead of wood. These materials do not burn and do not collect flammable debris like the space between planks in wooden decking. Where appropriate on steeper ground, use retaining walls to reduce the steepness of the slope. This, in turn, reduces the rate of fire spread. Retaining walls also act as physical barriers to fire spread and help deflect heat from the fire upwards and away from structures. Rock or masonry walls are best, but even wooden tie walls constructed of heavy timbers will work. Put out any fires burning on tie walls after the main fire front passes.

On steep slopes, consider building steps and walkways around structures. This makes access easier for home maintenance and enjoyment. It also serves as a physical barrier to fire spread and increases firefighters' speed and safety as they work to defend your home.

MAINTENANCE

A landscape is a dynamic system that constantly grows and changes. Plants considered fire resistant and which have low fuel volumes can lose these characteristics over time. Your landscape, and the plants in it, must be maintained to retain their Fire safe properties.

- Always keep a watchful eye towards reducing the fuel volumes available to fire. Be aware of the growth habits of the plants within your landscape and of the changes that occur throughout the seasons.
- Remove annuals and perennials after they have gone to seed or when the stems become overly dry.

- Rake up leaves and other litter as it builds up through the season.
- Mow or trim grasses to a low height within your defensible space. This is particularly important as grasses cure.
- Remove plant parts damaged by cold weather, wind or other agents.
- Timely pruning is critical. Pruning not only reduces fuel volumes but also maintains healthier plants by producing more vigorous, succulent growth.
- Landscape maintenance is a critical part of your home's defense system. Even the best defensible space can be compromised through lack of maintenance. The old adage "An ounce of prevention is worth a pound of cure" applies here.

SUMMARY AND CONCLUSION

Notification of fire conditions is a key element of occupant fire safety.
Notification should be taken seriously but not cause excessive alarm or panic. Messages should be concise, providing needed information without being overwhelming and foster confidence but not overconfidence in the fire protection systems present, *etc.* In designing systems, consider:
- Multiple sensory modes (sound, sight, touch) to accommodate various age groups, the sight and hearing impaired, *etc.*
- Redundancy, *e.g.*, using a combination of general alarm klaxons, flashing lights, and voice messages, to appeal to different levels of experience and comprehension.

Instruction concerning appropriate actions is a desirable supplement to alarm notification. Active systems such as auditory alarms, voice messages, *etc.*, can be reinforced by passive information modes such as signage, well-placed ambient lighting, and other features that reinforce correct fire-safety behaviors.

It has been pointed out that stereotyped measures for fire safety specified by various building codes are inadequate in that they can result in both under-protected and over protected buildings. With a better understanding of the characteristics features of compartment fires, the building designer will be in a better position to predetermine the nature of fire and to select the most appropriate way of dealing with it. He can either design compartments for minimum structural damage without installation of special equipment (defensive approach) or he can provide special equipment for detecting and suppressing the fire (offensive approach) or better still combine both.

Ultimately the designer must identify the causes of eminent fire which could include, Naked flame/smoking/children playing, lightning, Faulty equipment, Faulty electrical installation, Arson, Mishandling flammable liquids, misuse of electricity etc. and efforts should be made to curb these unforeseen or glaring causes from Planning/Design stage, Specification of materials, Compliance with Building and fire code, Firefighting Readiness, Provision for Fire escape as a panacea to efficient fire safe built environment.

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