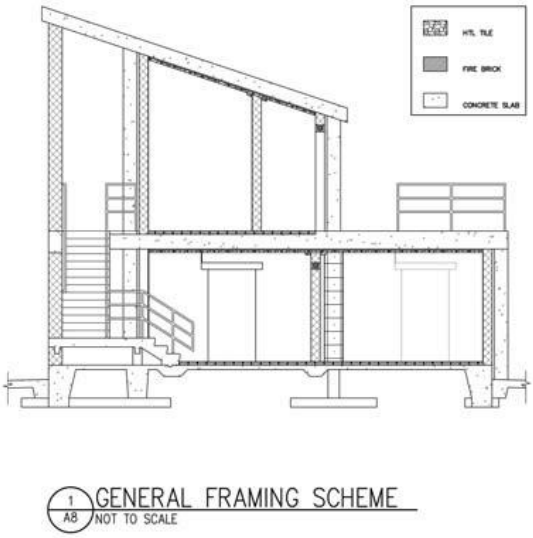
Burn Building
Basics 103

By William E. Glover



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BURN BUILDING BASICS 103

INTRODUCTION

This brief is intended to offer a basic understanding of issues relating to the repair of an existing live fire training structure (burn building), or the construction of a new building. Over the years these structures have been built all over the world, frequently utilizing minimal resources. These buildings are simple concrete and masonry shells in which firefighters repetitively ignite and extinguish fires during training exercises. The simplicity of the typical structure often results in a casual approach to its design and construction. Indeed, some burn buildings are expected to have only a relatively short life of perhaps two to ten years.

We are not architects, nor structural engineers, nor fire protection engineers. We are builders. Our general construction company has constructed about four hundred commercial structures over our sixty plus year history; including schools, hospitals, universities, fire stations, office buildings and pretty much every other kind of commercial/institutional structure, short of high rises. Since focusing on burn buildings in the early 1990's, we have worked on well over one hundred live fire training structures; repairing them; renovating them; manufacturing and installing a thermal lining system in most; and assisting designers and contractors with detailing, budgeting and building them. I have served on the National Fire Protection Association's Technical Committee for Live Fire Training since 2000, and have spent countless hours talking with hundreds of firefighters about fire training and the structures in which the training is conducted. It finally dawned on me in 2003 to share our experience in this pamphlet (this is the third edition) as these unique structures prove to be a challenge to every design and construction team confronted with a live fire training structure project.

Many burn buildings have been constructed over the last three decades for a number of reasons. Training has become more sophisticated as firefighting and fire science continues to develop. Firefighter training has become more than an objective - it is now a mandate. In the past, abandoned buildings (acquired structures) were burned down by fire departments as a training exercise. However, the supply of such buildings has dwindled and environmental regulations are so stringent that many departments find obtaining approval to burn acquired structures to be too much trouble. Finally, the number of firefighters required to protect a community increases in direct proportion to the general population. In growing communities, departments must continuously train new recruits and career personnel. This growth fosters the demand for additional burn buildings.

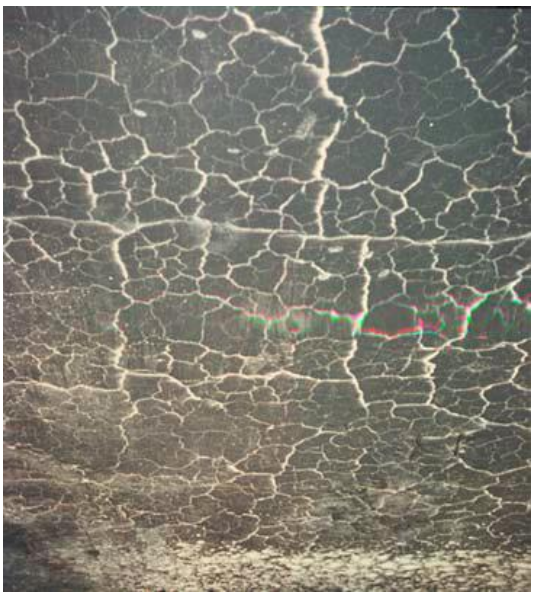
An increased demand for training requires a new approach to burn building construction. Departments now realize that the casual approach results in buildings that prematurely fail and become too great a safety liability to be used for fire training. Facility Managers often consider the structure to be a costly liability and nuisance as opposed to an asset. The very nature of the use of the building often leads to neglect of the structure. These buildings endure the most abusive environments. People expect the impossible from these buildings, yet they send their most valuable assets (personnel) into the structures every week. Still, it is rare that appropriate maintenance funding is allocated to ensure the structure is safely maintained. Police stations, fire departments, schools, governmental centers and recreation centers are all meticulously maintained. However, and unfortunately, where personal safety is placed in serious jeopardy on a daily basis, there is rarely funding available to ensure the maintenance of a safe training environment for the very individuals who protect the safety of the general public.

We at High Temperature Linings have concentrated on developing a responsible approach to burn building design and construction since 1991. In that time we have inspected, renovated and/or protected hundreds of live fire training structures. We have documented successes and failures and have been exposed to a lot of great ideas. The designs that we promote for new live fire training structures incorporate those ideas, as well as our developments in protective lining technology.
Again, this paper is our attempt to arouse the reader's interest in conducting further research into properly dealing with existing live fire training structures, or those that are being considered for new construction. Limited details are provided herein, but we encourage you to contact us with specific issues, concerns or questions about your particular structure. We will attempt to lead you in the right direction. Further, there are many site issues to be addressed when planning a new facility. Those issues are not discussed herein. Please feel free to contact us for more information on those issues.

USE AND ABUSE

For those of you who have not experienced live fire-training exercises, we will take a moment to summarize operations ongoing in a burn building. Burn buildings are generally concrete or steel structures in which firefighters arrange fuels to be ignited and extinguished for training exercises. These fuels are usually "Class A" (wood, straw and paper products). Certain newer facilities contain controlled propane or natural gas burners and steel props to simulate uncontrolled fires. During a normal training day, firefighters may ignite and extinguish these fuels many times. One ignition and extinguishment of a fire is called an "evolution". Three or four evolutions per hour during the course of a training session is normal. The session may last four hours for one department. It is not unusual for several departments to use the same structure in one day. Therefore, a structure could see thirty to fifty evolutions during a busy day. A certain amount of heat soaks into the structure when an evolution is conducted. More heat sinks into the structure with each successive evolution. By the end of the day the building is saturated with heat and will take a full day to cool off. The building may not have a chance to fully cool if training is ongoing the next day.

The size of the room, the size of the fuel load, and the average duration and number of evolutions will all affect the temperatures generated in the building. A typical "Class A" loading, including a bale of hay and two to four wooden pallets, will develop temperatures of about 200 degrees Fahrenheit near the floor and about 900 to 1100 degrees near the ceiling. It is not uncommon to experience ceiling temperatures between 1300 to 1700 degrees. Once the fire is allowed to fully develop, firefighters extinguish the fire using pressurized water delivered with fire hoses. Fire hoses are capable of delivering hundreds of gallons of water per minute at pressures of generally 50 to 100 pounds per inch. Some of the water immediately converts to steam, expanding 1700 hundred times its volume. This pressure plays havoc with the firefighters and the building. In addition to steam and the effects thereof, the building is subjected to its worst enemy ~ thermal shock. What is thermal shock? Have you ever taken a hot glass from the dishwasher and immediately placed it under a cold stream of water? What happened? The glass will often shatter. That phenomenon is called thermal shock. When a material is heated or cooled to extreme temperatures, and then suddenly subjected



Crazing

to oppositely extreme temperatures the material tries to react by expanding or contracting. The characteristics of the material may not allow it to adjust so quickly. When this happens, the binding element within the material fails. Such failures often show up as simple cracks; such as in structural concrete ceiling or floor slabs. Occasionally the reaction is more violent, as with concrete explosions. Concrete can actually explode like a hand grenade if water inside the concrete turns to steam and is unable to escape. The pressure developed by the steam is greater than the tensile strength of the concrete. When this happens, chunks of concrete and stone are blasted into the room with extraordinary force. More frequently however, the concrete has cracked over time and steam escapes through those cracks. Eventually, reinforcing within the concrete corrodes and large slabs of concrete fall away from the ceiling or walls. These are called Spalls.

Spalls result in weakened concrete sections. When a slab begins to spall, it is a clear indication that the slab has been exposed to too much heat and, consequently, is failing.

Spall

Spalls usually expose reinforcing steel. Subsequent fires then work on the reinforcing which eventually loses tensile strength. A structural concrete slab relies on both the compressive strength of the concrete and the tensile strength of the reinforcing steel. Once either property is compromised, the structural integrity of the slab is compromised.

In summary, concrete deterioration progresses as follows: As a building absorbs heat, the walls and slabs expand. Rarely is the building designed to compensate for this extreme movement. Frequently, expansion cracks develop in the slabs and walls. Those cracks often do not present structural concerns. In addition, however, the products within the concrete (sand, cement and gravel) are all expanding and contracting at slightly different ratios. Further, the extreme heat begins to affect the cement binder holding everything together. Eventually, the binder will soften, and particles of sand, gravel and cement separate. When this occurs, fine cracks develop in an irregular pattern called crazing. When a slab shows crazing, it is a sign that the concrete is suffering from heat. However, a structural problem still may not exist. Eventually, water and steam penetrate the slab through these cracks and micro-cracks. This moisture finds its' way to the reinforcing steel that is critical to the strength of the slab. The reinforcing begins to corrode, developing pressure from crystallization within the slab. After a period of time, the bond between the concrete and steel fails, resulting in an un-reinforced section of concrete that is now simply hanging onto the rest of the slab. This is called a delamination. More water builds up in the void between the concrete and steel. When that water turns to steam, it blows the loose un-reinforced concrete off (a spall). Again, reinforced concrete slabs rely on the great compressive strength of concrete and the tensile strength of steel. These elements must be bonded together. When concrete and steel are no longer bonded, structural slabs are severely weakened. We have inspected slabs that have entirely delaminated horizontally into two un-reinforced slabs above and below a mat of reinforcing steel that now serves no purpose except, perhaps, to

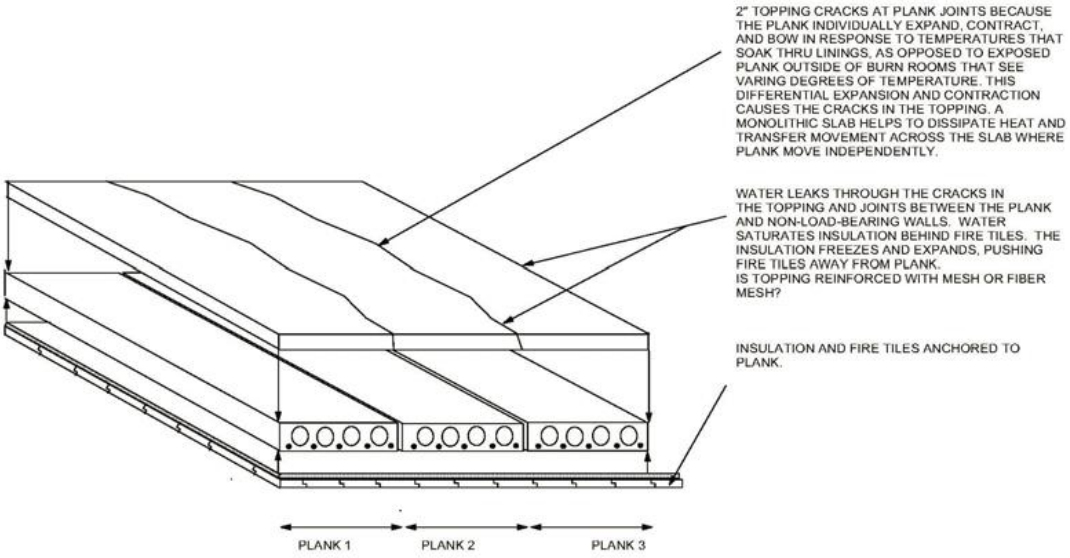
Expansion Crack

act as a cage to keep the top layer of concrete from collapsing to the floor.

Many of the same reactions to heat and steam are ongoing inside masonry walls that support many slabs and roofs in burn buildings. Masonry generally deteriorates slower than concrete. This can be attributed to the fact that some concrete masonry products contain pre-fired materials that have already reacted to a considerable level of heat associated with manufacturing. Also, concrete block walls are relatively porous allowing vapors to escape without immediate cracking or explosion. Nevertheless, many, if not most burn buildings will show cracking in masonry bearing walls. These cracks are commonly found near the corners of buildings and frequently do not present structural stability problems, though they should be repaired to prevent further deterioration. In many cases, an appropriate recommendation for these cracks is to saw cut a straight joint in the wall along the line of the crack and to simply leave it. This will act as an expansion joint to minimize future cracking in that area. Consult with your structural engineer.

A general comment about using structural concrete plank in burn buildings - please don't. Whether they are solid plank, with standard reinforcing, or hollow core, pre-stressed plank, we discourage their use in burn buildings. This is a complicated discussion as it relates to many issues such as bearing conditions; expansion and contraction; differential movement; topping designs; fire resistance; etc. Bottom line - plank are not ideally suited for burn building environments which include extraordinary heat and thermal shock. Planks tend to differentially expand and contract, cracking toppings above plank. They almost invariably allow water to leak through floor systems. Linings applied to the ceiling of a structural slab (or system of plank) are designed and intended to protect the slab/ plank from the heat and thermal shock developed in the burn room below. The systems are not intended to deal with water that could leak through the slab/plank from above, accumulating behind the lining. Accumulated water can saturate the insulation used in many lining systems, freeze and expand. The forces developed with ice expansion are extreme, and can easily damage both the structure and the linings, resulting in serious hazards to the users of the facility. See the graphic below.

Typical corner expansion crack



Water leaking through structural systems is a serious concern on any structure; however the concern can be greatly addressed and mitigated with proper structural design, maintenance and inspection procedures. We will also address regular maintenance and inspection procedures in this document.

Designers have also included light fixtures, power outlets, door and window details that have all quickly failed. Doors and windows are a particular maintenance headache and must be thoroughly considered during the design stage. It is rare to see a seasoned burn building with doors and windows still in operable condition. In summary, many typical building details which are fine in normal structures, simply do not work in burn buildings. This is not always obvious even to professional designers. When dealing with this type of live-fire training structure, experience is critical.

GENERAL DESCRIPTION OF BURN BUILDINGS: TYPE OF CONSTRUCTION

Historically, when designing any building, Engineers research past successes and failures and try to copy what worked. This is especially true of burn buildings. Unfortunately, there are simply not many burn buildings in any given locality. Therefore, local architects who are employed to design burn buildings often have never designed a burn building before and may never design another.

Many burn buildings constructed over the last forty years utilize concrete block walls carrying concrete slabs, while some have brick veneers and firebrick interior walls. Some have protective linings, although most do not. Some buildings last for thirty years, and others, that appear to be of similar construction, last only a few years. People wonder why. Frankly, we do too. We believe it primarily has to do with the quality of materials and workmanship, the size of rooms, the numbers of openings in each room and, most importantly, the frequency of use and adherence to standard operating and maintenance procedures.

Rather than getting into a long discussion on the attributes and flaws associated with each approach, we will simply comment on the one recurring theme with failed buildings.

MOVEMENT. Everything that is good or bad about a burn building design relates in some way to movement. Every detail that goes into a burn building must allow for movement while satisfying operational objectives. From the building's structural frame, to doors and windows, to lining systems - the ability to expand and contract without cracking, spalling, warping, etc., is critical.

PREVIOUS ATTEMPTS FOR SOLUTIONS

In the past; engineers have often over-designed structures to allow for "sacrificial mass" in walls and ceilings. This "extra" concrete was installed to allow for spalling without rendering the structure unstable. This over-design is still frequently implemented. Unfortunately, the extra concrete proves to be costly, ineffective and unsafe. We have experienced several instances of concrete failure that nearly caused serious personal injury. You only have to experience this once before you realize that concrete and structural concrete masonry and/or steel elements require protection from fire.

In the 1970s, a large cement manufacturer began to market their refractory concrete for use in cast-in-place concrete burn building structures. Refractory concrete has a cement binder that is more resistant to high temperatures. The material also contains aggregates that have been pre-fired. Refractory concrete works well in furnaces and boilers where thermal shock is controlled. However, it is not generally considered "structural" material and is detrimentally affected by the horrendous thermal shock found in burn buildings.

Classic Delamination of Refractory Structure

Portland cement concrete will generally crack and spall when overheated. This is not necessarily desirable, but cracks and spalls serve as warning signs to the user that the building may be seeing too much heat and may indicate that the structure is becoming unstable. Refractory concrete generally does not behave in the same way. Spalls and cracks are minimized but there is deterioration occurring. Micro-cracks are allowing steam to penetrate to the steel reinforcing which begins to corrode, developing internal stress within the slabs. Many times, refractory slabs appear to be in fairly good condition when they are, in fact, completely delaminated and ready to fall. HTL has worked on several refractory structures where entire ceiling slabs were horizontally split, negating the effectiveness of the reinforcing. This presents very serious safety and stability concerns in any structure, but especially in a fire training building which is subjected to so many unusual stresses. Cast-in-place refractory materials are also about ten times more expensive than standard portland cement concrete.

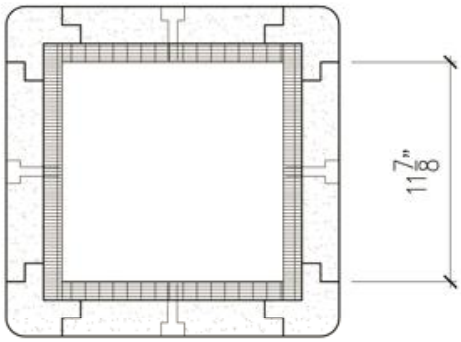
In summary, regarding cast-in-place refractory concrete - we have inspected several of these structures and most seem to behave in a similar manner. We strongly discourage the use of

refractory concrete for cast-in-place structural concrete. Such material was written out of the building code in Europe back in the 1970s.

Smaller departments have used shipping containers, temporary block and concrete buildings, pre-cast structures, and so on. Many of these solutions have offered excellent results for the small department that may be training infrequently (ten or twenty days a year). These small departments need to appreciate the potential for concrete spalling and/or explosions. It only takes one fire to bring about a potentially dangerous structural failure. Larger departments must have more permanent, safer facilities designed for near continuous use.

LININGS

As the number of building failures mounted around the world, the fire training community searched for a solution. The logical answer seemed to be some sort of protective lining to act as a barrier between the heat and the building. Training academies worldwide have repeatedly and unsuccessfully experimented with a myriad of lining materials for many years. Failed linings include sprayed-on refractories, rigid insulation boards, steel panels and various assemblies of similar components. We have researched this problem and have tested different materials for over ten years. Consequently, we have identified a number of deficiencies that may be associated with each or all of the aforementioned protection systems.



TYPICAL COLUMN PROTECTION
3 SD-2 1-1/2"=1'-0"

A thermal lining system for a burn building must meet the following requirements:

- It must thermally protect the structure to prevent temperatures exceeding five hundred degrees from reaching the structural frame. (Three hundred degrees is better).
- It must withstand extreme thermal shock.
- It must quickly expand and contract with extreme fluctuations in temperatures found in burn buildings (e.g. 1600° degrees Fahrenheit to 300° degrees Fahrenheit in seconds).
- It must withstand mechanical abuse from firefighter tools and direct hose streams.
- It must perform in the harshest of environments (i.e. sit in freezing weather for months and suddenly be fired up to 1,200 degrees without cracking).
- It must require minimal maintenance, as training divisions cannot afford downtime waiting for maintenance funding and repairs.

These are very unusual and difficult requirements to satisfy. Again, most engineers do not know where to start. Engineers have naturally been attracted to spray-on refractories since those products have been successfully utilized in high-temperature environments for centuries. Unfortunately, those products are designed for use in conjunction with a castable insulation in furnaces. The refractory, though referred to as “insulating”, is really not a good insulator. Heat soaks through in relatively short periods of time. Insulation is therefore required. Secondly, a spray-on application is monolithic and unable to quickly expand and contract. To provide access for

maintenance and repairs, large furnaces are cooled down over several days - not in a matter of seconds. Simply put - spray-on refractories are not designed for live fire training facilities. They are designed for industrial applications. We typically find engineers specifying two or three inches of spray-on to be applied directly to the structure. This system unfortunately may not be insulating the structure from the excessive heat and may only be hiding the degradation that is occurring behind the lining.

Another lining approach is to apply rigid insulation boards to the interior surfaces of the burn areas. These systems provide much more thermal protection for the structure and have proven to have varying degrees of success in lasting for adequate periods of time. Some academies have successfully made their boards last for years. Others have blown such systems away in a matter of months. The systems are generally limited to maximum temperature exposures of 1200° degrees Fahrenheit, are quite brittle and can crack in live fire training environments. Nevertheless, these systems offer a level of protection and an ease of replacement that is not found with spray-on systems.

Floating Refractory Lining

Other fire training centers have used steel panels to protect their structures. This approach has never made sense to us or to engineers familiar with structural fireproofing. You will be hard-pressed to find any resource that recommends fireproofing concrete with steel. You will find many that recommend fireproofing steel with concrete. Nonetheless, we have seen and replaced too many steel lining systems that have been great maintenance headaches while offering too little protection to the building and too much steam to the firefighters.

We are updating this document in 2011 to include a comment about at least one new system that is available on the market today. It includes steel panels installed over a layer of insulation. In that case, the insulation is providing thermal protection to the structure, while the steel panel is protecting the insulation. Though HTL still questions the logic of using steel in burn buildings, we do want to differentiate this insulated system from the un-insulated systems addressed in the previous paragraph.

Only time will determine the ultimate performance characteristics of the newer systems, so we encourage you to check them out for long term performance. Note that every lining system, (including the systems that we manufacture) and indeed, every burn building are vulnerable in some way, and they all require some level of care and maintenance.

We believe the best thermal lining system is a “floating” refractory liner installed over a rigid insulation barrier. This type of system offers resistance to mechanical abuse while providing excellent thermal protection to the structure. We have found that such a system provides the safest environment possible in which to conduct realistic live fire training. We therefore manufacture a refractory tile that is an interlocking unit, which encapsulates a barrier of calcium silicate insulation. The refractory material is a special blend of ingredients that are extremely resistant to thermal shock while maintaining excellent abrasion resistance, with high compressive strengths comparable to cast in place portland cement concretes. The system is able to expand with high temperatures and contract rapidly as water is applied. Though the tiles offer little thermal protection, the backup insulation kills most of the heat before it soaks into the structure.

All lining systems are relatively expensive. Indeed our system is probably the most expensive system on the market. We sell it because it outlasts other systems by factors of two to ten times and makes sense when running life cycle analyses. Nevertheless, long ago, we recognized the need to develop new building designs that make the most efficient use of the lining system installed, regardless of the chosen system. A discussion of this approach follows.

First, please be aware of a most important basic principle. Burn rooms that are protected with thermal linings will be generally hotter than rooms that are not lined. All burn rooms, whether lined or not, will absorb a certain amount of heat (energy) with each evolution. Therefore, burn rooms get progressively hotter and reflect considerably more radiant energy with each additional evolution. You should experiment with each burn room to develop standard operating procedures that will ensure that fires are monitored and kept under control so that the rooms are not overheated, threatening the safety or life of the firefighters using the room. HTL assumes no liability for environments and/or conditions created by the user in burn rooms. System 203 is intended to be used to protect burn rooms that are operated in strict compliance with the National Fire Protection Association's Publication 1403, Standard on Live Fire Training Evolutions, latest edition.

NEW STRUCTURES

Selection of Design Team - HTL encourages the Owner to hire an experienced engineer to design the new structure. We work with a number of engineering firms around the country. Feel free to contact our office for guidance. The structure is typically built by a local contractor and the owner hires HTL to install our lining systems. By hiring HTL directly, the owner can benefit from HTL's input during the design and construction stages. This approach is advantageous for a number of reasons:

Spokane, WA

1. The owner benefits from the experience offered by both the engineer and HTL.
2. The owner benefits, both economically and politically, with the participation of a local general contractor.
3. The owner benefits as HTL can make inspections and offer constructive criticism during the construction stage without concern of retribution from the contractor.
4. The owner benefits as the cost of the lining systems, usually about 1/3 of the cost of the entire project, are not marked up by the general contractor.

This approach makes sense regardless of the linings you use. The important point is to find experts that you can trust to understand your training objectives and long term goals for the structure and the training program.

Unfortunately, most engineering firms, facility project managers, and contractors have little to zero experience with burn buildings. The proposed structure, as described by the fire department, appears to be an easy project. However, we find that fire training officers and fire chiefs have difficulty communicating to engineers the challenging environment that the building will be subjected to. For many reasons, the designers rarely "get it" and often proceed to construct a simple structure with load bearing walls and concrete slabs. They incorrectly assume that these non-combustible materials will do the trick.

Engineers often spend too little time contemplating these designs because design fees are often inadequate. Procurement officers and facility managers envision a very simple structure - a shell of a building without interior finishes or electrical or mechanical systems. The engineer sees the same thing. The two parties agree to a small design fee of say 5 to 10 percent to design the facility. The fee is particularly small when you consider that most burn buildings cost from $300,000 to $1,000,000. This fee will simply not cover the cost for the engineer to perform extensive research. Do not skimp on a 7%-10% design fee that controls how effectively you spend the other 90 to 93% of your money. Remember, the quality of the design directly impacts the quality of your training for the next 20 years.

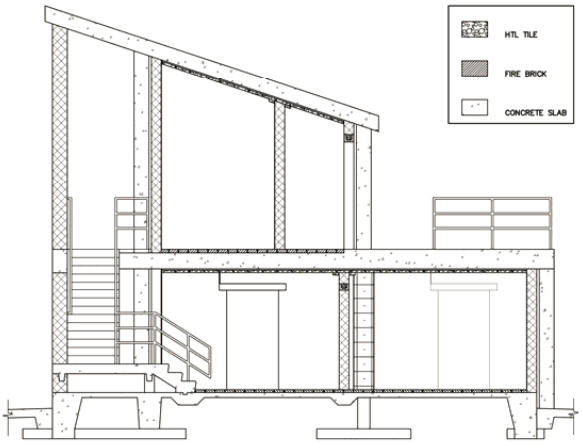
Typical Steel Plate Door

Of course, every engineer performs some level of research. If he is at all successful, he begins to realize that this little structure is not so simple. Sadly, he realizes this too late, since his fee is already negotiated. He now has no room to do the research, and to engineer and draft the many unusual details that he really should complete if he is to deliver a successful project. Consequently, engineers are often forced to do the best they can with a limited design budget. Sometimes they have to simply hope it works. Bottom line - hire a professional that has proven experience with burn buildings that are still working well. Check references!!!!

Upon completion of the construction documents, you will be ready to put the project out for bids from general contractors. The design will specify commercial materials and may even include a structural concrete frame that normally requires the skills of a larger commercial contractor. However, larger commercial contractors are busy building larger commercial buildings. You may therefore end up with a list of small contractors bidding on a small job that requires more experience than those contractors possess. We have worked as subcontractors on a number of such projects. We watched one 1300 square foot building take nearly a year to build. In summary, ensure your engineers and contractors have proven track records.

BASIC DESIGN CONSIDERATIONS

Building Frame - All structural elements should be protected from extreme heat and steam. All lining systems are expensive ~ so try to minimize the amount of lining that is required. Therefore, minimize structural elements (columns, beams, bearing walls). We recommend getting rid of as many, if not all, load bearing walls as possible. They are large structural surfaces that require protection. Instead, go with a structural concrete frame utilizing columns supporting flat structural slabs. Avoid beams. They are very expensive to protect. Most slabs can be designed to be flat, though they may be thicker than you would ordinarily specify for a given span between columns. The additional thickness will allow room to accommodate slab to column connections. The additional thickness is also attributed to the slope that is required on top of the slab to drain water to the perimeter. Remember, you have to form the suspended slab anyway. Another few inches of concrete are a minor expense that is easily offset with flat slabs that save costs in formwork and protective linings.

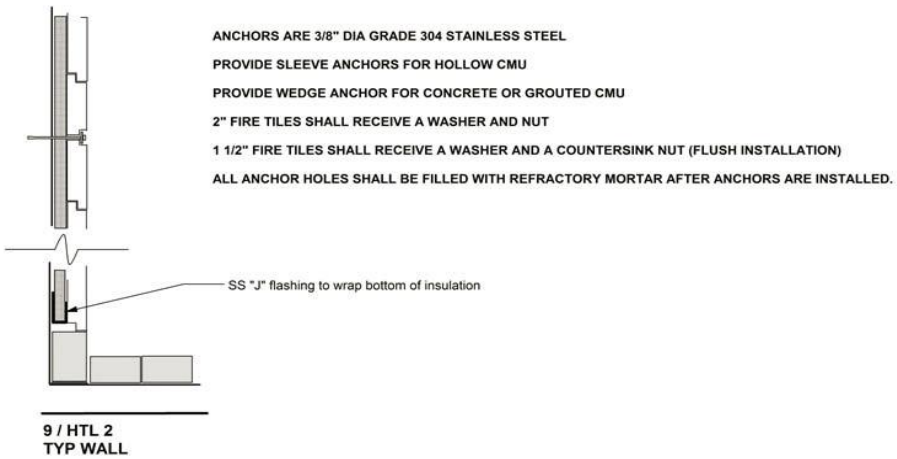


1 A8 GENERAL FRAMING SCHEME
NOT TO SCALE

Walls - Walls can be non-load bearing architectural infill panels as opposed to structural. Non-load bearing walls may be constructed of concrete masonry units with or without firebrick veneer or protective linings. The block will degrade over time and will periodically require replacement. The replacement cost of this non-load bearing material is negligible relative to the initial cost of lining protection. If your training academy is large and uses the burn building on a nearly daily basis, we would encourage you to protect portions of the walls in certain rooms to minimize the hassle of maintenance. This is a project specific consideration.

Floors – First, all suspended structural slabs should be treated with a cementitious waterproofing to ensure superior protection to the structure. Note that all slabs should be "wet cured" to receive this treatment. Commonly used chemical curing compounds will interfere with the bond between the waterproofing treatment and the slab.

We find that loose laid medium duty firebrick is the most cost effective way of permanently protecting concrete floors. Inside existing structures, you may place angles in doorways to hold the brick in place and cast a concrete ramp to transition from the unprotected floor to the brick. New buildings may be designed with depressed slabs to receive the 2 ½" thick brick. The brick are to be placed tight against one



another without mortar or bedding materials (dry set). The joints in the brick will eventually become filled with dirt and ashes. This will "tighten the system up" over time while allowing water to filter in between, thus eliminating pooling on floors and the associated burnt knees experienced by firefighters crawling through boiling hot water.

All floor surfaces should have a minimum of a 2% slope (1/4" fall per 12" of run) to drain water to the building exterior through scuppers along the exterior walls. The scuppers should be designed to be large enough (16"x8") to carry debris being sprayed to the scuppers with fire hoses. They should have covers so they may be closed during cold training exercises when light is not desired. And the covers should be designed so they may be left in the open position when burning to provide combustion air to the fire. You may contact us for typical details.

Stairs - Keep steel stairs out of burn areas. If possible, keep all stairs out of burn areas. If necessary, concrete stairs should be used and protected on the underside. Provide steel nosing's as hose couplings damage raw concrete tread noses.

Make sure hand rails are attached with wall brackets that protrude from the wall sufficiently to allow for a firefighters gloved hand. Don't forget to allow for the brick floors at the top and bottom of the stairs.

Typical Chop Out/Ventilation Hole

Chop Outs (ventilation simulators) - These openings should be protected. Secondly, heavy-duty plate steel joist hangers should be installed to receive wood joists that will be periodically replaced. The joist hanger should be deep enough to allow placement of a 2 x 4 stacked on top of a 2 x 6. This will allow trainees to cut through the 2 x 4 only, leaving the 2 x 6 undamaged to maintain a safe roof penetration.

Doors and windows - New door and window shutters should be surface mounted to the building exterior with pintle hinges. This will allow shutters to expand and contract without affecting the building. A number of options exist in shutter design - from manufactured units, to 1/4" steel plates, to doors fashioned from channels to receive 2 x 6s that can be easily replaced as they burn away. You are welcome to contact HTL for specific recommendations and details for your project.

Movement - Every detail should provide for movement. Doors, windows, lining systems, walls and structural frames should all "flex". Masonry walls require expansion joints built in at appropriate intervals (usually every 8 to 12 feet). Walls should receive a # 4 vertical reinforcing bar at 32" on center and the reinforcing should extend from the floor to the very top of the wall. The wall should be held down from the ceiling approximately ½ to 1 full inch to allow the non-load-bearing wall to expand vertically without touching the structural slab above. Once the wall meets the slab above, it becomes a load-bearing wall and may not have the foundation or strength to carry the load. Braces can be installed where the wall meets the slab above to restrain the wall from lateral movement. Again, talk to us for details.

Virginia Beach, VA

Frames should be eliminated in window and door openings. Frames are typically made of steel that will expand in the opening as they are heated. This is a real problem as doors and windows may bind, trapping a firefighter in the burn chamber. Such expansion may also place tremendous stress on the masonry opening, causing cracks at lintels, etc.

Linings must be able to move with fluctuating temperatures without failing. See previous discussion on this issue. Floors must also be allowed to flex or be protected with flexible linings.
Temperature Monitoring Systems – You could install a temperature monitoring system, comprised of a temperature recorder and temperature sensors (thermocouples) strategically placed throughout the structure. However, it is critical to understand that a measurement of temperature is not a measurement of the radiant energy that your personnel will be exposed to. Measuring radiant energy in a burn room is much more complicated and it is difficult and somewhat impractical to permanently install such a system in a burn building. Radiant energy is your enemy. HTL strongly recommends that you develop standard operating procedures that are based upon experimentation with your particular structure, protective lining, and fuel. Standard operating procedures should be strictly followed to control safe environments in burn buildings. See a later discussion on standard operating procedures.

When the temperature monitoring system is complete, you should conduct test burns throughout the building to facilitate the development of standard operating procedures. This will help you determine the size of the fire loads that may be safely ignited in each room. For instance one room may safely handle one bale of straw and two pallets while another larger room may handle four pallets.

The temperature monitoring system serves three purposes:

Modern Graphics Recorder

1. To protect your firefighters? – Years ago, we would recommend the placement of a thermocouple approximately 30" off the floor near the entry doors to the burn rooms. The purpose of this sensor was to allow your safety officer to know the temperatures your recruits were experiencing as they entered the rooms. However, we have learned that thermocouples offer only a “relative” measure of temperatures within a burn room. Further, the wall surface temperature dramatically affects the temperatures recorded by a thermocouple mounted on a wall, approximately 30” off the floor. That thermocouple senses a temperature that is tempered by the wall temperature since the wall is a thermal "sink" and stores both high and low temperatures. The firefighter is experiencing the air temperature that may be considerably higher or lower than the temperature sensed by the wall-mounted thermocouple. Our field tests have proven radical variations between temperatures measured by wall-mounted thermocouples and those measured by sensors dangled throughout the room. These variations can exceed 100%. This phenomenon is confirmed in our conversations with the Fire Sciences Laboratory at the National Institute of Standards.

As wall thermocouples are often incorrectly assumed to be accurate safety devices, we believe they should be eliminated on future projects. We believe it is better to provide no information in lieu of false information. Training officers using common sense and years of firefighting experience ensure a safer training environment than a metal temperature sensor mounted to a concrete wall.

Should you still elect to install a thermocouple at this elevation, we very strongly recommend that training officers be firmly and repeatedly advised that such monitoring offers only a "relative" measure of the heat in the room and that such information may be very inaccurate. Install placards on the exterior of all training structures with temperature monitoring systems stating something like this: "Temperature readings displayed and recorded by the temperature monitoring system recorder may be considerably lower than actual air (gas) temperatures. Do not use the temperature monitoring system to determine safe fire loadings. Use only standard operating procedures." The same placard should be installed on the temperature recorder panel housing.

2. To protect your building - place a thermocouple between the lining system and the structure to measure temperatures soaking through the lining. This will allow the department to monitor performance of protective lining systems over time to ensure that years of burning are not affecting the structural integrity of the building that is hidden by the protective linings. Since this thermocouple is measuring a slow rate of heat rise, you may be confident of the accuracy of the information.

3. To monitor your building when others are using it (ever rent a car?) - The monitoring system acts as a watchdog when outside companies are using the structure. If someone gets hurt or a building component is damaged, you will be able to download the data off of the recorder to see if temperatures recorded were those that would be expected if the standard operating procedures had been followed. If the temperatures greatly exceed the norm, someone probably went overboard with fuel loads.

The temperature recorder may log temperatures onto paper as well as saving data to a floppy disk. Newer models have more sophisticated graphic displays and record data to internal and external memory devices. As a minimum, the unit should have a digital display to allow safety officers to concurrently view temperatures during training exercises. We recommend the use of type "K" thermocouples. They are relatively inexpensive and have a high enough temperature rating to allow for fire training activities.

When a temperature monitoring system is installed into an existing building, conduits will have to be run exposed. All conduits should be kept out of burn rooms unless they can be installed behind protective lining systems. Conduits delivering thermocouple wire to burn rooms must be run on the outer surfaces of walls surrounding the room. If conduits are installed on the exterior of the building, care should be taken to route them below burn room windows. Conduits and wire left exposed above windows will be damaged by heat and direct flame impingement rolling out of the opening.

Pre-Engineered Metal Buildings - There are at least two companies that sell pre-engineered metal burn buildings and calcium silicate board linings in burn rooms. The advantage of this approach is that the buildings have already been designed or may be custom designed to accommodate your layout requirements. The disadvantage is that these structures are light duty construction and the linings can require considerable maintenance. Finally, we believe the cost of these structures is somewhat inflated and suggest, if you want a metal building, that you talk to a local supplier of pre-engineered buildings to obtain competitive pricing for a structure. Make sure you specify heavy gauge (18 to 22 gauge) wall and roof panels for ladder drills, etc. Calcium silicate panels may then be purchased and installed separately.

Pre-Engineered Conventional Structures – We prefer concrete and concrete masonry structures that have been designed and improved many times over the years. Designs may be revised to accommodate your site. Specific details relating to structure, doors, windows, railings, linings, etc.,

have already been developed and tested in the field. As previously mentioned, we can put you in touch with engineers who can offer a number of basic of designs that you may wish to review. If you are an engineer, we can offer many details to incorporate into your designs.

NECESSITY FOR STRUCTURAL SURVEYS ON EXISTING BUILDINGS

By now you may be wondering about your existing facility. Does it have any of the problems discussed above? Would you know if it did? The fact is that certain symptoms of serious problems that exist in burn buildings are not obvious to the untrained eye. Indeed, some are not visually obvious to the trained engineer. A delaminated refractory slab may not be proven to exist until core samples are taken from the slab.

As mentioned earlier, burn buildings attract little attention from maintenance personnel; yet, they serve as training environments for volunteer and career professionals who share one objective - the safety and welfare of the general public. Isn't it ironic that the general public does not reciprocate with funding for safe, adequately maintained training environments?

Regardless, many jurisdictions are recognizing the real liabilities associated with older burn structures that have not been surveyed to ensure safety. In addition, the National Fire Protection Association Publication 1403, Standard on Live Fire Training Evolutions, requires that periodic structural surveys be performed by qualified structural engineers on all live fire training structures. This only makes sense. We recommend the following scope of services for such a health check.

The survey should provide the information you need to make educated decisions regarding safety, repairs and structure life. These important issues should be addressed before investing in renovations, linings, temperature monitoring systems, or upgrades to doors, windows, etc. To provide you with adequate information, we propose that the following services be provided by licensed structural engineers with live fire training structure experience:

A. Visit the project and perform a preliminary review of the entire structure. This preliminary review is to focus on the condition of the existing structural elements (columns, beams and slabs), windows, doors, hardware, and temperature monitoring and control systems. This inspection shall determine the extent of testing services and Engineering studies that shall be required. The engineer shall coordinate the work required of the structural engineering consultants and testing agency.
B. Confirm building dimensions, including thickness and locations of exterior and interior walls; floor and roof dimensions and elevations; and floor and wall openings.
C. Visually evaluate the condition of the building structure, documenting all observable deficiencies caused by exposure to fire, water and weather. Photographs shall be taken showing the overall structure and typical types of defects. Deficiencies shall be recorded and mapped for all floor, ceiling, roof, stair and wall surfaces.
D. Specify location, quantity and type of field tests required to evaluate the condition and capacity of the structure.
E. Testing may include the following:

    1. 4" diameter concrete cores to be taken from existing concrete.
    2. Prior to coring, an examination can be made of the designated coring locations to help avoid cutting embedded items. This examination shall be performed using a

Removed Core Reveals Delaminated Slab

pachometer. (A pachometer is a magnetic device that helps to detect the presence of near-surface magnetic materials. When items such as reinforcing bars are detected, adjustments can then be made in the actual coring locations to help avoid cutting embedded items. However, deeply embedded steel items, or non-magnetic items, cannot be located.)

3. Prepare concrete core samples for compressive strength testing as described in ASTM C42 and tested in accordance with ASTM C 39.
4. Perform soundings of concrete slab areas in accordance with ASTM D4580, Procedure B to determine possible delaminations in the concrete.
5. If needed, petrographic evaluation of concrete core samples could be performed utilizing applicable procedures within the provisions outlined in ASTM C856. The purpose of the petrographic evaluation is to provide general information regarding the condition, quality, and design of the concrete mix and placement. The analysis shall focus on indications of aggregate reactions, signs of carbonation, assessment of apparent cracks and embedded objects and the overall condition of the concrete matrix. This test might not be required as determined by the Engineer.
6. If necessary, perform compressive strength testing on concrete masonry unit (CMU) prism samples in general accordance with ASTM E 447.

F. Testing crews shall ship all samples to laboratories for evaluation and testing. A laboratory shall prepare a detailed report to include all findings. The report shall be forwarded to the Engineer for their use in developing recommendations for corrective work that may be required to the structure.
G. Structural engineers shall analyze the test results and determine the load carrying capacity of the structure and its capacity for attaching lining systems.
H. Engineers shall prepare a written report that documents the findings of the survey and testing, providing dimensioned plans of the building and making recommendations on the suitability of investments in upgrades to the structure.
I. If necessary, in order to determine the typical temperatures achieved by training personnel, the Owner's personnel shall be asked to conduct a typical burn. The burn chamber shall be wired with thermocouple wire and temperature measurements taken with portable temperature monitoring equipment. This information shall be supplied to the Structural Engineer and Testing Agency and shall be included in the final report to the Owner.
J. A written report shall detail findings as they relate to existing burn building details and configurations and make recommendations for changes to configurations, systems, doors, shutters and linings. The report shall offer estimates to make recommended changes. Further, estimates shall be provided for any corrective and/or upgrade work as recommended by the Structural Engineer. At the Owner's request, competitive bids for said repairs and or upgrades shall be solicited. Separate proposals shall be offered for lining systems for the Owner's consideration.
K. The report shall be bound with reports from the Engineer and the testing laboratory to provide a comprehensive document that advises the Owner of the existing condition of the burn building(s) with recommendations for corrective work and/or improvements.

Solutions for existing burn buildings – Many existing structures are so compromised by the fires that have been conducted over the years that the structure may require reinforcement with new structural elements to transfer loads to foundations. We have completed work on a number of projects where we designed “rooms within rooms” in existing structures. The new rooms include structural elements to carry the loads imposed by the new rooms and transfer those loads to new foundations placed in the basement of the existing structure.

We often work with customers who do not have the funding to fully line the structural elements in their existing facility as this can prove to be a very expensive proposition. We therefore design solutions that may include linings of only ceilings or even portions of ceilings such as in a corner. The walls are then protected with less expensive materials that may require replacement every few years. An example might be to simply lay a concrete block wall up in front of a load-bearing wall. The new concrete block will take most of the abuse and will deteriorate over time. Finally, a small addition to an existing facility can allow burning in the addition, while the existing structure continues to be used for cold training.

In short, existing buildings are always a challenge but we are usually able to come up with an acceptable solution that addresses the needs and concerns of all parties involved. Do not be discouraged with your existing facility, simply open your mind to all of the possibilities that are available to you to continue and improve your training program.

Maintenance and Operating Procedures - One of the greatest challenges to safe live fire training is the lack of maintenance. Maintenance of the live fire training structure is absolutely critical to ensure a safe environment for firefighter training. The Authority Having Jurisdiction (Owner/Operator), is directly and solely responsible for providing the funding and personnel to properly maintain training structures that endure such extreme environments. Without an appropriate, continuous, inspection, reporting and maintenance program, it is impossible for the AHJ to claim that the safety of the firefighting personnel has been given top priority.

It is also unquestionably incumbent upon the firefighter training staff to adhere to clearly established Standard Operating Procedures that define and control fuel types, fuel loads, evolutions, and pre and post-burn inspection/reporting procedures. Staff should participate in the development of the SOP, and thereafter embrace and actively promote the program. Staff must resist the historically prevalent “hotter is better” philosophy that is frequently promoted by the fearless, “macho” mentality that is so pervasive in the fire service. Definitive SOPs are not just a good idea; they are now required by the NFPA 1403 Standard on Live Fire Training Evolutions. Note that the 2012 edition includes specific language requiring the development of SOPs that will define and control the environments created.

In our effort to address both maintenance and SOPs, we have developed a number of documents that are included as an Appendix to this document. Though they are simply copied herein, without editorial comment, we hope you will find this information to be helpful as you address maintenance and SOP requirements for your structure.

Where do we go from here?

Our mission is to develop a partnership with the fire service to develop new ideas for safe live fire training structures; standard operating procedures; and a progressive, proactive approach to fire training. We strive to safely accommodate an acceptable level of realism in permanent live fire training structures in order to reduce the requirement for acquired structures where so many injuries occur. We are committed to this goal.

CLOSING

In summary, I leave you with the most basic advice.

1. If you have an existing burn building, have a survey performed to ensure that the structure is still a safe training prop.
2. If you are planning a new structure, use a qualified and experienced team of experts who understand the environments found in live fire training facilities and who have a proven track record.
3. Remember: a burn building is a piece of real estate that is an asset. Assets should be protected, not expended.

Bill Glover is President of High Temperature Linings, a manufacturing, design and construction firm specializing in live fire training structures around the world. Comments or questions are welcomed. You may reach Bill Glover by calling 800-411-6313 x201 or by e-mailing him at will@firetrain.com.

APPENDIX TO BURN BUILDING BASICS 103

March 23, 2002

TO ALL USERS OF TEMPERATURE MONITORING SYSTEMS IN LIVE FIRE TRAINING STRUCTURES

We wish to advise you of an issue relating to temperature monitoring systems installed in live fire training structures.

Many temperature monitoring systems have been installed over the years in an attempt to provide the fire service with accurate information as to the temperatures being generated in burn rooms. This information is important to the training officer to understand the following:

a. The highest temperature in the room as measured by the thermocouple that is mounted on the ceiling.

b. The temperature at a level of approximately 24-30 inches off the floor to measure the temperature encountered by firefighters crawling into the room.

c. The temperature between the protective linings and the concrete structure to monitor the performance of the lining system over a long period of time.

We have learned over the years that thermocouples mounted to the wall and ceiling surfaces read a temperature that is tempered by the mass of the wall or ceiling. In other words, the wall and ceiling surface temperatures are going to be lower than the air temperature that is trying to heat up the mass of the wall or ceiling. Imagine putting lasagna in an oven set at 350° degrees. The lasagna may take an hour to heat up to the air temperature of the oven. This is the same phenomenon experienced in burn rooms. The walls and ceilings are mass that is absorbing heat similar to the lasagna. We have measured wall and air temperatures that vary by as much as 70-100%. E.g. air temperature of 368° degrees and wall temperature of 230° degrees.

Therefore, during the first several evolutions of a training day the thermocouple will report temperatures that are considerably lower than the temperature of the air. Then, for a while, the thermocouple will report temperatures that are closer to the actual air temperature. However, as the day wears on, the thermocouple will actually begin to report temperatures that are higher than

the air temperature. This is the result of cooling the air temperatures with bursts of water while the mass of the wall is storing the extraordinary heat generated in the room during the day of training.

We have consulted with various experts in the field of temperature monitoring and have concluded, at least for the moment, that there is nothing we can do to improve this situation. We are dealing with the laws of nature. The only way to provide more accurate readings would be to dangle thermocouples in the air throughout the room. This is impractical in a training environment.

We still believe the temperature monitoring system is a tool that provides a relative measure of what is occurring in a burn room. However, it is important to understand, particularly with the thermocouple that is mounted near the floor, that the temperatures reported by the temperature monitoring system are inaccurate relative to air temperature and should not be used to measure "safe" air temperatures. Should you still elect to install a thermocouple at this elevation, we very strongly recommend that training officers be repeatedly and firmly advised that such monitoring offers only a "relative" measure of the heat in the room and that such information may be very inaccurate. Install placards on the exterior of all training structures with temperature monitoring systems stating something like this: “Temperature readings displayed and recorded by the temperature monitoring system recorder may be considerably lower than actual air (gas) temperatures. Do not use the temperature monitoring system to determine safe fire loadings. Use only standard operating procedures”. The same placard should be installed on the temperature recorder panel housing.

We encourage all training divisions to rely on PASS devices mounted to the firefighter to ensure the firefighter is not exposed to extreme temperatures. We understand these are available with rate of rise measuring capabilities, but do not know of one that measures a set temperature as adjusted by the user. If you know of one, please let us know.

Finally, the thermocouple that is installed between the protective lining system and the concrete structure is measuring the amount of heat that slowly soaks into the structure. This is accurate. This thermocouple is not affected by thermal imbalance that occurs in the confines of the burn room. This concealed thermocouple is an important component of your system.

Please make sure all personnel using your facility are made aware of this condition.

We realize this is an undesirable situation and are still looking for a better way to provide accurate data to the training officer. Your comments, questions and suggestions would be appreciated.

Sincerely,

HIGH TEMPERATURE LININGS

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February 17, 2012

Dear Chief Training Officer:

Bill Glover, President of High Temperature Linings, has been sitting on the NFPA Technical Committee on Fire Service Training for ten years. In his work with the committee, and in his participation as a member of design/construction teams on over one hundred new live fire training structures (burn buildings), he recognized that many in the fire service were using NFPA 1403, Standard on Live Fire Training Evolutions, as a stand-alone Standard Operating Procedure. In fact, NFPA 1403 is a broad standard that addresses many types of training, and different types of fire training structures and/or fire training props. It is imperative that Standard Operating Procedures be developed by each fire training center that applies NFPA 1403 to the particular structure, and to each burn room within the structure, that is being used by the fire department.

Further, it is apparent that most fire training academies are exercising too little control of fuel loads and numbers of evolutions conducted in permanent fire training towers, and that many in the fire service do not have an appreciation for the critical nature of the radiant energy that is developed as multiple successive fire evolutions are conducted. Many in the fire service believe that the installation of a permanent temperature monitoring system in the burn building allows training officers complete control in maintaining safe training environments. However, it is important to understand that a relative rise in temperature does not equate to the same relative increase in radiant energy produced. In fact, as temperatures increase, and as successive fires are conducted, the amount of radiant energy increases exponentially. To date, there is not an effective means of measuring the radiant energy produced in a live fire training structure. Further, permanently installed temperature monitoring systems are only relatively accurate in reporting actual gas temperatures that exist in different parts of a burn room.

Consequently, the NPFA Technical Committee on Fire Service Training has included language in the 2012 edition of NFPA 1403 that addresses this issue. The new standard requires that “burn sequence charts” be developed to define fuel loads and numbers of evolutions that can be safely conducted in each burn room of the live fire training structure. The standard includes the following language:

> **7.3.1** The AHJ shall develop and utilize a safe live fire training action plan when multiple sequential burn evolutions are to be conducted per day in each burn room.
>
> **7.3.2** A burn sequence matrix chart shall be developed for the burn rooms in a live fire training structure.
>
> **7.3.2.1** The burn sequence matrix chart shall include the maximum fuel loading per evolution and maximum number of sequential live fire evolutions that can be conducted per day in each burn room.

7.3.3* The burn sequence for each room shall define the maximum fuel load that can be used for the first burn and each successive burn.

7.3.4* The burn sequence matrix for each room shall also specify the maximum number of evolutions that can be safely conducted during a given training period before the room is allowed to cool.

7.3.5 The fuel loads per evolution and the maximum number of sequential evolutions in each burn room shall not be exceeded under any circumstances.

High Temperature Linings encourages our customers to immediately take a pro-active role by taking the following steps:

1. Understand the difference between temperature and radiant energy.
2. Understand that you can create environments in permanent live fire training structures that are a threat to your turn out gear and your safety. Remember, a permanent live fire training structure is designed to withstand thousands of live fire training evolutions without seriously affecting the integrity of the structure. Consequently, if you are not planning and controlling your evolutions, the environments created could be worse than those encountered in actual structure fires. Quite simply, many structures would collapse under the same conditions.
3. Develop Standard Operating Procedures that apply NFPA 1403 to the particular structure that you use for your fire training. We are attaching a sample of what that SOP might look like. Of course, you must develop SOPs that apply to your specific structure. The attachment is intended to simply offer ideas.

We hope this information is useful to you, and we strongly encourage you to contact us with comments and/or recommendations.

Thanks, and please be safe!

Sincerely,

HIGH TEMPERATURE LININGS

Sample Standard Operating Procedures
February 2012

The following language is a sample standard operating guideline that is offered by High Temperature Linings (HTL) to encourage your thought and action in developing your own SOP to address live fire training evolutions conducted in your specific live fire training structure. This sample may not address all issues that need to be addressed in your structure, and may not even make sense for your particular structure. You must develop your own language. This document is simply intended to offer ideas. HTL disclaims liability for any personal injury, property or other damages of any nature whatsoever, whether special, indirect, consequential or compensatory, directly or indirectly resulting from the publication, use of, or reliance on this document. HTL also makes no guaranty or warranty as to the accuracy of completeness of any information published herein.

Welcome to the (name of your training academy). As a training instructor, you are the most important component of our mission to provide an effective, safe and comprehensive training experience for firefighters utilizing our facility. Your participation is greatly appreciated. Of course, your commitment to safety is appreciated most by the families of the men and women that we train. Your professionalism and commitment to our cause to protect lives and property is the foundation of our training program. Thank you for your time, your ideas, and your contributions to our efforts in meeting our goal of providing the best, safest live fire training possible.

Our academy recognizes the National Fire Protection Association (NFPA) 1403 Standard on Live Fire Training Evolutions (1403), latest edition, and is dedicated to ensuring adherence to this standard before, during and after every live fire training exercise conducted. To that end, each of our instructors is required to become thoroughly familiar with this standard, to the degree that he/she understands all aspects of the standard and agrees to enthusiastically advance its' spirit in providing safe, effective live fire training.

Further, we do not believe it is good enough to adopt NFPA 1403 without applying the standard to our specific structure. Each training structure is unique. Some structures are single story; others are multiple stories. One structure may be a poured in place concrete structure with a structural protective lining system (SPLS) only on the ceilings; another might be concrete block with a few rooms that are completely protected with SPLS. One structure could be in Palm Beach County, Florida with sweltering ambient temperatures, while another is in Boston, Massachusetts, dealing with freezing temperatures on the day of training. The following are just some of the factors that will affect how NFPA 1403 would be applied to a specific structure.

a) Number of stories
b) Construction (concrete, concrete block, metal building)
c) Type and quantity of structural protective lining system (SPLS)
d) Type of temperature monitoring system (TMS), if any.
e) Size of burn rooms
f) Number of burn rooms
g) Type, size and number of windows / doors
h) Type, size and number of passive ventilation openings / chop outs
i) Fuel utilized (straw, excelsior, pallets, propane gas, natural gas, or a combination)

j) Type and number of means of egress and means of escape.
k) Prevailing winds
l) Altitude

As you travel to other jurisdictions, you should look for SOPs that apply to the particular training structure you are using.

Consequently, the (enter name of training academy) staff drafted this SOP to apply NFPA 1403 to our specific live fire training structure. It is important to understand that this SOP is a supplement to 1403 and is not intended to revise the standard in any way. Should there be a discrepancy between this document and 1403, you are to apply that requirement which has the more stringent language. This SOP does not address all chapters or paragraphs of 1403. Rather, it only addresses certain paragraphs that need to be clarified to understand how that part of the standard is being applied to our particular structure. Remember, you must be thoroughly familiar with all 1403 language and adhere to the entire standard as you conduct live fire training exercises.

Our live fire training structure (LFTS) is designed to provide a safe training environment for live fire training conducted in strict compliance with NFPA 1403. The LFTS has (enter number) levels. The structure includes (enter number) burn rooms. Each room has its own characteristics and will behave differently than another room in the same structure. We will therefore address the following specific issues as they relate to each room.

A. Construction of the (enter name of training academy) LFTS
B. Pre-burn inspections 1403.6.2.6; 1403.7.2.1.1; 1403.5.2.1
C. Fuel loads for each evolution conducted in the room (see "Sequential Live Fire Burn Evolutions"). NFPA 1403.7.3
D. Maximum number of evolutions for the room in a given training period before allowing the room to cool off (see "Sequential Live Fire Burn Evolutions"). NFPA 1403.7
E. Placement and configuration of fuel
F. Ignition procedures
G. Ventilation techniques and/or issues. NFPA 1403.7.2.3
H. Water supplies NFPA 1403.4.11
I. Post-burn inspection 1403.7.1.2

Burn Sequences: When conducting evolutions in a burn room, one must be aware of the following basic facts:

1. Larger burn rooms and rooms with higher ceilings will have more cubic feet of air than smaller burn rooms.
2. Generally speaking, with a given quantity of fuel, the lower the cubic footage in a room, the higher the temperatures and more rigorous the environment will be.
3. As the number of openings in a burn room increase, the available ventilation area increases, resulting in typically lower temperatures and less severe environments.
4. The construction of the burn room will affect how much hotter the room will become with each successive evolution. All burn rooms will retain a level of heat with each burn. The temperature and radiant heat in the burn room will increase with each additional evolution. At some point, every room

will become too hot to safely conduct further training. Outside environmental conditions might also affect the conditions within burn rooms.

5. The burn sequence for each room should define the maximum fuel load that can be used for the first burn and each successive burn. Typically, the fuel load for the second burn should be smaller than the fuel load for the first. The fuel load for the third burn should be smaller than that for the second……and so on.
6. The burn sequence for each room should also specify the maximum number of evolutions that can be safely conducted during a given training period before the room is allowed to cool.
7. The burn sequences for the burn rooms in our structure shall be: (see attached table)

A. Construction of the (enter name of training academy) LFTS

Our LFTS is a rather unique structure that has been specifically designed for Class A live fire training. The construction includes a structural concrete frame (slab, columns, beams and shear walls) that has been protected with a structural protective lining system (SPLS). Most of the walls of the structure are non-load bearing, non-structural infill panels developing both exterior and interior walls. The walls are constructed of concrete masonry units (CMU). The walls contain horizontal reinforcing @ 16" o.c. vertically, and vertical reinforcing bars that have been grouted into the CMU at 32" on center. All of the floors are covered with loose laid fire pavers that absorb much of the heat before it gets to the slab on grade and the structural floor / ceiling slabs. The brick also helps to temper the effects of *thermal shock* to the structural concrete.

Therefore, the structural components of our building should be in great shape through many years of service. However, the non-structural walls are exposed to the heat, water and *thermal shock* that is associated with fire training. Therefore, those walls will slowly deteriorate over time, requiring periodic replacement and/or repairs. We are therefore vigilant about continuously inspecting our walls to ensure that there are no loose blocks, or pieces of block that have become dislodged, presenting a hazard to our personnel should a loose piece fall. This requires all training officers to be aware and to collectively participate as "inspectors" each time they visit the facility. Any block(s) that present a hazard must be reported immediately to (enter name here or position here) by completing the attached form and submitting it to (enter name here or position here). Further, no training shall be conducted in any room containing loose block or portions of block. However, frequently, with permission from to (enter name here or position here), you may remove the loose materials and continue to train in the affected room.

The LFTS also has steel drainage scuppers, and door and window shutters that are designed to expand and contract without binding. Further, they have specially designed latches that allow you to "pin" them in the open position while any live fire training is being conducted. The shutters are intended to be closed, but not latched, during the evolution until the compartments are ventilated by opening the shutters. Though the shutters are constructed with heavy plate steel, and are expected to offer a reasonable service life, it is expected that they will require periodic maintenance and replacement as they tend to warp with time. It is therefore important that each door and window be inspected on a continuous basis before, during and after all training sessions. A warped shutter may be difficult to operate in the cold state, much less when heated during a training session. Further, latches may bind or

be difficult to operate or to pin in the open position. Therefore, again, you are expected to report any deficiencies to (enter name here or position here) as soon as they are found. Training evolutions are to be terminated in any room having the deficient shutter, or any room that would require ingress or egress through the subject shutter while training, or in the event that the RIT should be required.

Make sure you have been trained on the proper operation of all shutters and scuppers.

Our LFTS is also equipped with a temperature monitoring system (TMS). The system includes thermometers (*thermocouples)* that are mounted as follows:

Each burn room has at least one thermocouple mounted on the surface of the ceiling to monitor the theoretical highest temperature in the room. Behind each surface mounted thermocouple is another thermocouple that is concealed between the structural protective lining system (SPLS) and the structural concrete, to monitor the amount of heat that soaks through the SPLS. Finally, there is at least one thermocouple that is mounted on the wall of each compartment that monitors the temperature at that point on the wall (30" above the floor). All thermocouples are connected via low voltage wire running through concealed conduits, to a *temperature data recorder* that displays the temperatures being recorded throughout the structure. The data recorder also stores all data to an internal memory and to a removable memory device. The data can be uploaded to programs in our training offices for viewing, manipulation (charting, historical recordation, etc.) and storage. IT IS ABSOLUTELY CRITICAL TO UNDERSTAND THAT THIS EQUIPMENT IS NOT INTENDED TO REPLACE THE ABSOLUTE REQUIREMENT FOR CONTINUOUS AND VIGILENT OBSERVATION AND MONITORING OF ALL BURNS AND BURN ROOM CONDITIONS BY THE SAFETY AND IGNITION OFFICERS SUPERVISING THE LIVE FIRE TRAINING EXERCISE.

The temperature monitoring system is installed to act as a "watch dog". As long as you are following this SOP, conditions in the LFTS should remain controlled and safe. However, if someone does not follow this SOP, the temperature monitoring system will record conditions that fall outside the range of conditions normally encountered when adhering to the SOP. Therefore, a record of non-compliance will exist to allow us to take appropriate disciplinary action.

It is also important to understand that temperatures in a burn room do not necessarily reflect the level of radiant energy developed. Temperature does not measure radiant energy, and radiant energy is the number one threat to firefighters in any live fire scenario. The simplest way to explain this is to understand that a thermocouple that is placed into the flame of one candle will detect the same temperature as one that is placed into the flame of ten candles. Yet the radiant energy produced by ten candles is ten times higher than that produced by one candle. This radiant energy is absorbed by your turn-out gear, and at some point, your gear will fail. It is very difficult to measure radiant energy in a LFTS. This is the primary reason that we have adopted the aforementioned Burn Sequence Charts. We have experimented with the LFTS and have found that we can safely conduct training evolutions of the size and quantity specified in the chart. DO NOT EXCEED EITHER THE FUEL LOAD OR THE QUANTITY OF EVOLUTIONS SPECIFIED IN THE BURN SEQUENCE CHART.

B. Pre-burn inspection 1403.7.1; 1403.7.2.1; 1403.7.2.1.1; 1403.5.2.4.1

1. As discussed in A, walk through the entire structure looking for loose concrete block and or floor brick. Any block(s) and/or floor brick that present a hazard must be reported immediately to (enter name here or position here) by completing the attached form and submitting it to (enter name here or position here). Further, no training shall be conducted in any room containing loose block or portions of block. However, frequently, with permission from to (enter name here or position here), you may remove the loose materials and continue to train in the affected room.
2. Inspect all doors and windows to ensure proper operation. Report any deficiencies to (enter name here or position here) as soon as they are found. Training evolutions are to be terminated in any room having the deficient shutter, or any room that would require ingress or egress through the subject shutter while training, or in the event that the RIT should be required.
3. During the walk thru, pay attention to ceilings and walls that are protected with SPLS. Any fire tiles that appear to be loose, or hanging, shall be reported immediately to (enter name here or position here) by completing the attached form and submitting it to (enter name here or position here). No training shall be conducted in any room containing loose fire tiles. Further, report tiles that have missing mortar over the tile anchors (bolt hole filler). Though this is not an issue that will prevent training, it is a maintenance issue that must be addressed periodically by training staff.
4. Make sure that you have been properly trained on the operation of the temperature monitoring system, and that the system is powered up and recording temperatures before commencing with any live fire training. Make sure the recorder has a sufficient quantity of data logging paper in the paper bin and that the pens are recording temperatures (have ink). Report any problems to enter name here or position here).
5. Check hand rails and guardrails, and stair nosings to ensure they are not loose. Report any deficiencies.
6. Means of egress in the room. NFPA 1403.4.13.5 / Means of escape. NFPA 1403.4.13.5 and NFPA 1403.7.2.3

   Rescue route (entry and egress) for rapid intervention team. NFPA 1403.4.13.5
   a. Each burn room in the live fire training structure has a minimum of two means of escape. Doorways serve as the means of escape in all burn rooms except burn rooms 202 and 203. In those burn rooms, the window shall serve as the second means of escape. Fires shall not be set in rooms 202 or 203 unless a ladder has been placed and tied off at the window serving as the second means of escape.
   b. The instructor-in-charge shall walk through the live fire training structure before each training session to ensure that all means of egress are clear of debris and/or other obstacles and that all door and window shutters are operable and that latches are pinned in the open position.
   c. The safety officer shall walk through the building prior to each evolution to ensure the means of egress are clear of debris and/or other obstacles.
   d. The safety officer shall ensure that the floor hatch in room 203 has been properly closed before each evolution.
7. Inherent and/or peculiar hazards (floor openings, fall hazards, obstructions, etc.) NFPA 1403.5.2.4.1 Ensure that any horizontal or vertical means of ventilation are operational and not obstructed. There are chop simulation openings in the ceilings of rooms 202 and 304.
8. Potential drainage issues. NFPA 1403.5.2.4.1

a. Ensure that all drainage scuppers and/or pipes are clear and operational.
b. Look for damage to the floors (spalls and/or missing firebrick pavers) that result in puddles. Report any problems to (enter name here or position here). Note that puddles of water present a hazard as the heated water burns the knees of crawling firefighters.

9. Walk around the exterior of the structure looking for loose blocks, debris and/or equipment that might be on ledges or sills that could be knocked off the building. Take appropriate measures and/or report deficiencies.
10. Inspect burn racks to ensure they are properly placed and in good operating condition and that there is not a chance for a rack to fall over during training. Take appropriate measures and/or report deficiencies.
11. Make sure there are NO stored fuels in the LFTS prior to conducting evolutions.
12. Inspect all fire sets, to ensure they are in compliance with the Burn Sequence Chart with respect to the size of the fuel load and the type of fuels being utilized.
13. Inspect the standpipe system to ensure valves are operational and that there are no obstructions preventing access to the standpipe.
14. Inspect and operate the separate standpipe system for the safety lines utilized during ignition.

C. Fuel loads for each evolution conducted in the room (see "burn sequences"). NFPA 1403.4.12 and NFPA 1403.7

The Burn Sequence Chart (BSC) specifies the maximum fuel loads for each fire set conducted in each burn room. Further, the BSC specifies the maximum number of evolutions that may be conducted in each burn room during any training session, before the rooms are allowed to cool for a minimum of four hours. Further, all ignition officers are to adhere to the following guidelines:

1. Never use fuels other than those specified in the BSC.
2. Only Class A fuels are specified. No Class B fuels are allowed in the structure.
3. Always use burn racks provided, and only load the fuel as directed in the instructor training course.
4. When racks are not provided, only configure fuel loads as directed in the instructor training course.
5. Ensure that pallet wall hooks, used for concealed fire evolutions, are secure.
6. Ensure that the Safety Officer inspects every burn room prior to every evolution and that an Ignition Officer and a second person with a charged safety line ignite each and every evolution.
7. The Ignition Officer and the second person shall carefully follow NFPA 1584 Standard on the Rehabilitation Process for Members During Emergency Operations and Training Exercises, 2008 Edition to avoid overheating turn-out gear and/or themselves.

D. Maximum number of evolutions for the room in a given training period before allowing the room to cool off (see "burn sequences"). NFPA 1403.7.3

1. The number of consecutive evolutions conducted in any burn room shall not exceed the maximum number of evolutions allowed per the Burn Sequence Chart during any one training session before allowing the room to cool**.**

E. Placement and configuration of fuel

1. Fuel loads shall be limited to that specified in the Burn Sequence Chart for the particular evolution.
2. Fuel shall be arranged in the burn rack provided.

3. Fuel loads may also be placed in designated burn areas indicated on the attached floor plans of the live fire training structure.
    a. Fuel loads shall be configured per the attached typical fire set configuration.

F. Ignition procedures

1. One person who is not a student shall be designated as the "ignition officer" to control the materials being burned.
2. The ignition officer shall wear full protective clothing, including SCBA, as required by NFPA 1043.4.8, when performing this control function.
3. A charged hose line shall accompany the ignition officer when he or she is igniting any fire.
4. Each evolution shall be ignited only by the ignition officer, in the presence of and under the direct supervision of the safety officer.
5. The decision to ignite the training fire shall be made by the instructor-in-charge in coordination with the safety officer.
6. Fires will not be ignited in rooms deemed to be overheated as determined by the instructor-in-charge in coordination with the safety officer.
7. The only fuel that is allowed in rooms 103 and 202 is hay or excelsior which is to be placed in racks provided.

G. Ventilation techniques and/or issues. NFPA 1403.7.2.3

1. Each training officer shall have received training on the proper ventilation techniques that are unique to this live fire training structure. See (enter name here or position here) for training.
2. After each evolution in rooms 103 and 202, the positive pressure ventilation (turbo blade) fan shall be positioned and operated for a minimum of 180 seconds to cool the room.
3. Vertical ventilation drills shall be conducted with a minimum of two students and one safety officer. The live fire training structure is equipped with removable safety railings and operable gates at the roof eve to allow for placement of roof ladders. After roof ladders have been placed and students have advanced to the sloped roof above rooms 202 and 304, the access gate shall be closed for the duration of the exercise. New plywood and joists (if necessary) shall be installed after each vertical ventilation drill to prepare for the next use of the prop. At the end of the training session, the weather cover for the ventilation penetration shall be placed over the fresh plywood / joists.

H. Water supply NFPA 1403.4.11

We wish to emphasize the following critical components of 1403 with respect to water supply.

1. 1403.4.11- The instructor-in-charge and the safety officer shall determine the rate and duration of water flow necessary for each individual live fire training evolution, including the water necessary for control and extinguishment of the training fire, the water supply necessary for backup line(s) to protect personnel, and any water needed to protect exposed property.
2. 1403.4.11.3 - Backup lines shall be provided to ensure protection for personnel on training attack lines.
3. 1403.4.11.2 - Each hose line shall be capable of delivering a minimum of 95 gpm (360 L/min).
4. 1403.4.7.5 - A charged hose line shall accompany the ignition officer when he or she is igniting any fire.

I. Post-burn inspection 1403.7.1; **1403.7.1.2; 1403.5.2.1**

Inherent and/or peculiar hazards (floor openings, fall hazards, obstructions, etc.) NFPA 1403.5.2.1

1. The safety officer and the instructor in charge shall both walk the structure at the end of the training session.
    a. Walk through the entire structure looking for loose concrete block and or floor brick. Any block(s) and/or floor brick that present a hazard must be reported immediately to (enter name here or position here) by completing the attached form and submitting it to (enter name here or position here).
    b. Inspect all doors and windows to ensure proper operation. Report any deficiencies to (enter name here or position here) as soon as they are found.
    c. During the walk thru, pay attention to ceilings and walls that are protected with SPLS. Any fire tiles that appear to be loose, or hanging, shall be reported immediately to (enter name here or position here) by completing the attached form and submitting it to (enter name here or position here).
    d. Make sure the recorder has a sufficient quantity of data logging paper in the paper bin and that the pens are recording temperatures (have ink). Report any problems to enter name here or position here).
    e. Check hand rails and guardrails, and stair nosings to ensure they are not loose. Ensure that removable roof railings are properly replaced and that gates are closed and pad-locked. Report any deficiencies.
    f. Ensure that all unused fuel is removed from the structure. Ensure that all fires have been knocked down sufficiently, but do not completely douse and remove embers. Leave embers to burn themselves out. (This procedure helps to minimize thermal shock to the training structure, contributing to the life of the structure.)
    g. Ensure that all corridors, stairs and means of ingress/egress have been cleared and cleaned.
    h. Ensure that the roof ventilation cover is in place along with fresh plywood and joist in rooms 202 and 304.
    i. Ensure that the floor hatch in room 203 has been properly closed.
    j. Inherent and/or peculiar hazards (floor openings, fall hazards, obstructions, etc.) NFPA 1403.5.2.1
    k. Ensure that any horizontal or vertical means of ventilation are operational and not obstructed. There are chop simulation openings in the ceilings of rooms 202 and 304.
    l. Ensure that all drainage scuppers and/or pipes are clear and operational.
    m. Look for damage to the floors (spalls and/or missing firebrick pavers) that result in puddles. Report any problems to enter name here or position here).
    n. Walk around the exterior of the structure looking for loose blocks, debris and/or equipment that might be on ledges or sills that could be knocked off the building. Take appropriate measures and/or report deficiencies.

SAMPLE TO BE REVISED TO APPLY TO YOUR STRUCTURE								
Maximum Fire Loads and Maximum Number of Evolutions for Burn Building								
Burn Sequence 1 - Pallets	4	4	3	6	2	3	4	4
Burn Sequence 1 - Bales	1	1	1	1	1	1	1	1
Burn Sequence 2 - Pallets	4	3	2	4	2	2	3	3
Burn Sequence 2 - Bales	1	1	1	1	1	1	1	1
Burn Sequence 3 - Pallets	3	2	2	3	2	2	2	2
Burn Sequence 3 - Bales	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Burn Sequence 4 - Pallets	2	1	1	2	1	1	1	1
Burn Sequence 4 - Bales	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Burn Sequence 5 - Pallets	1			1			1	1
Burn Sequence 5 - Bales	0.5			0.5			0.5	0.5
Burn Sequence 6 - Pallets				1				
Burn Sequence 6 - Bales				0.5				
Maximum # of Evolutions	5	4	4	6	4	4	5	5

Notes:

1. Maximum pallet size = 50 pounds of clean (untreated and uncontaminated) dry, rough oak pallets. Pallets made of anything other than solid wood components (no particle board, etc.) may not be used.
2. Bales are clean, dry, untreated, straw weighing no more than 70 pounds, from an approved source. Consult with Chief Training Officer.
3. See SOP for approved lighting devices.
4. Assumes 20 minute intervals between evolutions.