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FIRE SAFETY IN HISTORIC BUILDINGS

An Interactive Qualifying Project Report

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Abstract

This report presents findings on fire prevention in historical buildings. Several areas of fire protection have been touched on in the report. These focus areas deal with prevention, retrofitting, past fires and legislation dealing with fire prevention. A case study was performed on the Massachusetts Military Archive and Museum in Worcester, Massachusetts. The study provides possibilities that present several alterations and upgrades to improve the building against fire.

The group would like to acknowledge the contribution of the following:

Jonathan Barnett

Steve Seames - permission for the study of the Worcester Armory

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Introduction

This report presents a discussion on fires in historical buildings. We looked into the causes of fires in historical buildings and how they started and how the fires may have been prevented. For example, accidental and outdated electrical wiring have started many fires that have occurred in historical sites. Also, many historical buildings are planning on improving their fire protection systems to meet with today's codes and life safety needs. However, many of the buildings are federally owned and do not have to comply with the codes of the area. These buildings need special authorization to perform such renovations and improvements. Since these buildings are historical, laws that prevent improvements to the buildings govern many of them. On the other hand, some laws just prevent outrageous renovations from happening and it keeps the heritage of the building intact. After the building gets the approval for the improvements a design must be made and then the retrofitting process is implicated. This process has been performed in many buildings that the governing body thought that an improvement of the fire protection system was needed. With the research that was accomplished and the knowledge gained a case study of the Higgins' Armory in Worcester. The case study includes what systems the armory should consider to improve the fire protection of the building. The building contains archives and weaponry from the army and its' personnel in Massachusetts. Many conclusions can be made based on the presented information and the eminent concerns for the keeping of the heritage and the historical artifacts that are stored in the building.

Background and Research

The background required for this project was included in one class at WPI, FP3070, Fundamentals of Firesafety. Three out of the four group members took or are taking the class presently. Most things, however, were just common sense and a little brainstorming or idea session would suffice.

The research was undertaken for this project was substantially more in-depth. The group made two trips to the NFPA headquarters in Quincy, Massachusetts. During these trips the group gathered dozens our articles from fire related literature and compiled them to create the basis of the project. The group also used the WPI Library as well as the Somerset County Library in New Jersey for books relating to fires in Libraries and Museums. For laws and legislation regarding libraries and museums, the group used the WWW to find the government laws, and went to WPI and the Worcester Court House to find state and local laws. Finally the group toured the Worcester Armory several times to gain a firm knowledge of the conditions which were found. The background described above as well as the previously mentioned research gave the group its base for the following pages as well as the evaluation of the Worcester Armory.

Causes of Library and Historic Building Fires

Fire safety and protection is a growing concern in the historical buildings around the world. There is a concern for the tourists that visit the sites and for the priceless items that are stored in the museums, libraries, or historical buildings. Many of the historical buildings around the world are constructed from highly combustible materials, such as wood, cloth and asbestos. Historical building retrofitting and renovation is the updating of the existing fire protection devices if any to that of which a fire protection engineer has calculated and planned for the building in question. The goal of retrofitting historical buildings for new systems, whether it is pipes for sprinklers or wiring for smoke and heat detectors, is to provide the building with suitable life safety measures that comply with the area code or the extent of the protection that is wanted by the governing body of the historical building. "The introduction of sprinkler piping and heads into historical buildings requires a lot of planning and detective work if it is to be done without destroying the building. In many cases, creative and judicious use of existing construction can provide high levels of fire protection without major reconstruction." (Lauziere) Such designs are made so that they do not alter the building's structure in any way and that it keeps the internal environment of the building as if the work was never done. Most often the need of fire protection in a historical buildings does not occur until a fire occurs, and then it is known that the building need protection. Demands of fire protection create many concerns for the curators or others responsible for the welfare of the collections in the buildings and the buildings themselves. These authorities are reevaluating the building and the need for new or redesigned fire protection for their building.

The process of retrofitting and renovating buildings is a long and hard process. The building in question must be inspected and evaluated by the proper fire protection personnel. The inspection team then analyzes the codes of the area and interprets what is needed to be done to meet up to code. A fire detection system is then designed to fit the buildings needs and structure. After the analyzation process takes place a code expert must interpret the codes and identify overlooked problem areas for the new system. The fire protection plans must fit the codes for the state and county or the appropriate variances must be completed. Fire protection in historical areas must be designed with the best interests for the building and for the collectibles that are in the building, and also for the tourists that visit the building each day. The fire protection system is to protect the building and its collectibles from fire damage but the designer must also protect the collectibles from the fire protection service. For example, water sometimes causes much more damage than the fire itself. To counteract this, most libraries are switching to some sort of dry fire protection system or a system that can prevent extensive water damage.

During the analyzation of the codes the most difficult areas to comply with the code are means of egress and fire separation or compartmentation. In most historical buildings it is very difficult to plan for egress in the building. In some case staircases must be added to the exterior and even the interior to add a means of egress in the buildings. However, the building may not be easily manipulated to fit such things. So the original building design plays a crucial part on the compartmentation deign. In the placement of egress systems, the designer does not want to destroy or even alter the original fabric the historical building because the fabric, design or architecture may damage the buildings' significance and historical importance to its community. To solve the egress problems the building designer may divide the building into compartments. However, it may occur that a building may not be able to be compartmentalized and then a refuge area may be installed with fire rated wallboard and a separate supply of air and exhaust system to make up for the loss of compartmentation in the building. These are ways that some fire protection designs can substitute losses for other means of fire safety. Some of the smaller historical buildings lack adequate room to enlarge the staircase to comply with today's code.

To remedy this problem a designer may use empty space or ventilation shafts for the locations of staircases. On the other hand, most buildings are not blessed with this unused space where a staircase could be built. If the building does not permit the architect from placing a staircase inside the building then a staircase may be placed on the outside of the building as stated before. The Department of the Interior's standards must be used in the design of the staircase and but must look like a modern improvement to the building that does not alter the building's overall feeling and design. To further improve the fire protection of the building the persons responsible must be educated the fire protection system that was installed in the building. This should include facts about the system whether it be a sprinkler, or smoke detection system. Also, workers must be educated on the response times of the nearby fire departments and know the response times of the detection systems in the building. To further improve the system training the employees, depending on the items in the building or museum, to salvage the invaluable items that are stored in the building is an important addition to the fire protection system design. The training is very important to the readiness and successfulness of the fire protection system. Personnel trained in the fire rescue to evacuate the building of tourists to prevent any injuries to the visiting tourists. Salvage methods can protect the many artifacts that a building contains, salvagers can retrieve items if consumed by the flames and restore them the near original condition. Adequately trained personnel could even save the building for any fire damage at all because of adequate training, good response time, and knowledge of fire suppression and the fire system. These items are good qualities that a historic building must have to be prepared for the danger and destruction that fire causes.

Once a plan is drafted, an assessment of how the plan will work is performed with an actual test run of the designed protection system. When the data is collected, the firm responsible would review the plan and revise it according to the results of the practice run and make the plan perform more sufficiently and safely. The plan must be easily understood so in the time of need there are no problems with the interpretation of the plan and the understanding of how the is implemented. Planning is always ongoing it is never perfect there are always ways to change and improve the protection plan of the building. An actual fire incident will not occur that same as a modeled fire test. Most often the best test against a safety plan is to have an actual disaster and see how the plan worked under the real conditions. This will enable the planners to analyze it and then make more improvements on the plan to try to create an even safer plan. A system must have good response time and a quality assurance. The response time is crucial. A fire company can receive the distress signal from the building instantly but if the fire company arrives one hour after the fire started, there will be no building left to save. Quality assurance is needed so that the system and personnel are without doubt will not malfunction at the time of need.

In addition to those ideas, the system must not malfunction and leak causing the protected materials to be damaged by the protection systems. One preventative measure that should be checked is that there is no condensation collecting on the pipes. Too much condensation would cause corrosion and in the future leaks will be created from the corrosion. Wet and dry systems were designed to prevent this type of destruction of property.

The fire protection plan may also include "initially educate the persons responsible for the historic structures. This education should include a basic but complete course on automatic sprinkler systems." (Lauziere) The training should familiarize the personnel about the systems and techniques that are needed to operate and the protection system. It should eliminate any falsehoods like if "...one sprinkler head causes all sprinkler heads in the building to discharge copious amounts of water." (Lauziere)

Many historical societies are now upgrading their sites to meet the fire protection standards of today. This is because most historical buildings have little or no fire protection devices in the building and are potentially at great risk to sustain severe fire damage if one were to occur. Historical buildings are containers of vast cultural information, history and the wealth of knowledge from its old age. This is a great way to look at the buildings, but now look at it through the eyes of a fire. These buildings are made mostly of wood beams and timbers, which are extremely dried and easily ignited and very flammable. Most of these historical buildings contain an abundance of historical information, for example; books, paintings, uniforms, statues, or ammunition. These artifacts are precious to the culture of its surrounding society and the need for protection against losing any of these important items is necessary to preserve our culture and heritage which is preserved in the artifacts.

One of the most publicized newly designed fire protection systems is the system installed in the new British Library in London. The library's collection contains books collected over 200 years old. The building is serviced with very high tech systems including a close controlled air conditioning systems, sophisticated lighting, extensive fire fighting and detection equipment and many other systems for a modern building of that size to function and for protection. There are also many important items that were that were essential for fire protection in the English building. One of the most important aspects of the library is the book storage system. "The four levels of basement provide an excellent, stable thermal environment for the documents. However, they are beneath the drainage level and design against water damage has been extensive." (Cartwright)

In the design stages of the British Library many systems of fire protection were contemplated. An extensive system of exhaust fans with four hour rated ductwork was designed to provide the library with suitable ventilation. However, the ventilation in some cases disrupts the compartmentation of the building. To solve this problem, dampers were installed and are normally closed to keep the fire compartmentation intact. Also, "in all of the basement book storage compartments, natural smoke venting has been achieved via the use of smoke shafts and pavement outlets." (Cartwright) However even though some of the rooms were naturally smoke ventilated (.. .some area, particularly the plantrooms, have no direct connection with the external pavement." (Cartwright) Mechanical extract systems were installed to reach a ventilation rate, which can be achieved by naturally ventilating the first basement level

Halon systems were considered but however Halon systems have since been outlawed because of the harmful environmental impacts. A carbon dioxide system was also considered. Since the containers were expensive, dangerous and the life safety factors were high, the design was thrown away. Carbon dioxide systems do work but the system is not complementary the personnel that may be trapped or fighting the fire. The carbon dioxide removes the oxygen from the air removing the fires main ingredient and also removing oxygen kills the humans that are trapped or fighting the fire. However, because of the rare materials, that are located in safe rooms where the risk of human occupation is minimized or cut-off, are protected by carbon dioxide systems. The compartments (safe rooms) are on a stand-alone system. A stand-alone system, which means that each safe room, will not react to a fire in a nearby room. The release of carbon dioxide in these rooms will be manually from the security room by trained security personnel or fire fighters. The systems are monitored and controlled by the Building Management System. If the system is on automatic mode, two sensors in the protected room will need to be set off by heat or smoke in the safe room. This will release the carbon dioxide if the conditions are met for the automatic mode activation. All of the fire detection and protection systems are comprehensive and extensive. The sprinkler system, because of the library's need to be a dry system, will be a pre-action dry system will prevent any leakage on any of the books in the library. (A dry system was therefore required, but a fast response time desirable to minimize the extent of the fire damage caused while water was entering the system." (Cartwright)

A smoke detection system would be the activation system for the dry sprinkler in the library. The piping for the sprinkler system, whether it works through the building vertically or horizontally, it is encased in a brick shaft that matches the interior design of the area it is located. This provides security against any accidental leakage by trapping the water inside of the brick shafts and if necessary draining the released water to a safe drainage area. However, when water enters the sprinkler system it has unique drain system that will clear the system of the possibility of any leakages over materials in the library. This preventative measure occurs and remedies the situation. The sprinkler system also had some needs to be a dry system to also prevent the system from any leaks. When the chance of any water leaks the sprinkler, the brick shaft can also protect the library's materials from any damaging effects of the water.

The new British Library was built and the fire protection system was proved to be harmful to the materials contained in the building. To remedy the problem a new design was presented and then the building had to be retrofitted to give the Library the best fire protection system and to keep the library's intended environment stable and undisturbed by the alterations. The new fire protection system provides the greatest protection for the materials and the best life safety for the library personnel and its readers.

An example of a retrofit working for a historical building is the 350 year old Coleridge Cottage, where Samuel Taylor Coleridge lived. Coleridge is the author of "The Rime of the Ancient Mariner" and several other poems between the years 1797 and 1800. The historical Cottage contains "a building within a building, in which the original structure has been extended with a modern outer structure." (Fire Prevention 293) The decision for a protection system was proven needed because of the remoteness of the cottage to any fire departments. The nearest one is fifteen miles away at Bridge water, England. A fire in the cottage could quite possibly destroy the Cottage. "The National

Trust decided that a fire detection system and alarm system alone would not be suffice." (Fire Prevention 293) Thus making a sprinkler system an important part of the protection design. The National Trust is England's risk management board that conducts surveys and renovations of buildings in need of fire protection. The National Trust had a survey done on the Cottage by Colin Packer, the Trust's fire adviser. Colin Packer prepared a detail fire risk assessment that considered overall impact of the structural works, the interference that the retrofits will have on the buildings historic environment, and the potential water damage that could result from a sprinkler release. A sprinkler system was determined to "that sprinklers should be an integral part of the fire protection philosophy for Coleridge Cottage." (Fire Protection 293)

The sprinkler design is not only an effective design it would no create and deformations during construction or as a completed system. The system used LPC approved CPVC pipework that ranged from forty millimeters to twenty millimeters nominal diameter. Sizes were determined by hydraulic calculations specific to the design and to the Cottage. "Fifty quick response sprinkler heads, designed to operate at 68 degrees Celsius, protect all rooms. The sprinkler heads react to heat and fire more quickly than conventional heads, ensuring that any outbreak is quickly dealt with." (Fire Protection 293) The pipework installation achieved total concealment. The design of the sprinkler system was decided to be totally self-contained. "Domestic water available at the rear of the cottage was used to supply the system via automatic controls, a water tank with an effective capacity of 1400 liters and a pump arrangement specifically designed for this project." (Fire Protection 293) The water supply is maintained to handle two heads during activation. The activation of any sprinkler would automatically sound a local alarm and send a signal to the fire department.

The Smithsonian Institute is another example of in the growing historical fire protection industry. The Smithsonian Institution includes 15 museums, which range in age from over 130 years old to babies just under construction today. The Smithsonian has a central command center for which stores all of the fire appliances and appropriate personnel. Each building also contains all of the detection systems and suppressions systems main controls. In addition to the fire controls it also holds the H V A C controls and the building management equipment. The Smithsonian withstood three major fires in the past. In a 1965 blaze several scientific specimens were destroyed, and in 1970 another fire resulted in a million-dollar loss for the Museum of American History. The fire in 1979 made the Smithsonian Institute reevaluate the fire protection plan in the complex.

From this incident, the Institute put forth effort to exceed the modern fire protection and life safety codes of the day and design a new fire protection system for the Institution. However, according to the regulations federal buildings do not have to comply with the local and state codes in which they are located. On the other hand, the Institute wanted to have the best fire protection system that could be obtained or designed. Research for the upgrade and retrofit was performed in all of the buildings new and old. Many new designs were made and then analyzed and redesigned to fit the needs of the Institute and its buildings and artifacts.

The renovations done to the historic Smithsonian Castle included a complete smoke detection system in the entire building. Several series of smoke tests were performed on the system to ensure the accuracy and sensitivity of the installed system. State of the art ionization spot-type detectors were installed in enclosed rooms and the corridors. This gave the Castle superior protection against smoke and fire damage. In the open spaced rooms in the building complex, projected beam detectors were placed.

As a result of the elaborate building construction, the sprinkler system was not as easy to design. The sprinklers were encased in a horizontal facade system that blended with the Castle's detailing and architecture. The sprinkler pipes themselves were placed in areas out of view of the public most often on the office side of the corridors. In cases where the sprinkler heads were installed on the sidewall, the heads matched the decor of the room or corridor. Also, brickwork was used to conceal the piping throughout the complex just like the British Library, London.

There were several cases of no means of egress in the Castle. For this stairwells were added to two new locations were there was no egress for the public, for workers and fire fighters if needed. Another case was the addition of an enclosed stairwell that was built in the rooms that were renovated to construct an exit for a dead end on the fourth floor of the Castle. Compartmentation was also included in the renovations of the Castle. Floors were divided into fire rated compartments that were arranged horizontally and vertically. Fire and smoke doors were installed when needed. The emergency lighting and signs were improved throughout the Castle to improve emergency lighting and exit. After the renovations were completed only a trained eye can notice the fire protection improvements that were retrofitted in the Smithsonian Castle. More than 17 million dollars were spent on the fire protection improvements done to the Smithsonian Institute.

The Smithsonian Castle presented a unique problem to the protection design engineers. The system for the Castle must be totally disguised from public who tour the Castle. Retrofitting included many elaborate designs and techniques that incorporated the interior decorations and layout of the Castle with the design and layout of the extensive safety system. The disguised and hidden pipework concealed any signs of a sprinkler system or a smoke detection system. The fire protection system and newly built egression routes give the Smithsonian superior protection against fire damage and human injury in the Institute's Castle.

Another part of the Smithsonian's fire protection plan is the new Getty Center in California. One of the major protection measures is an emergency helicopter-landing pad for the center. This helipad includes fire department connections to fill airborne tanker units because of the extremely high tendency of brush fires in that area of California. The Getty Center has many intricate fire protection parts on the center's grounds. The center includes a one million-gallon resivior and has two pumps that power two water mains that create a dual loop of fire hydrants around the complex. Providing water to any location around the complex if needed. The complex also includes an emergency power system that can provide emergency power to the entire Getty Center. This power source serves the sites' complete emergency lighting system.

The Vizcaya Mansion, which is located in Miami, Florida, was dreamed by the "...late James Deering, who envisioned an American version of an Italian Renaissance villa and its gardens." (Firewatch Vol. 4 1985) During the time of the mansion's construction in 1914 it employed more than 1,000 people at the time when Miami's total population was only 10,000. The Vizcaya now serves as a museum of European art. The mansion is now self-sustaining institution in Florida.

Some of the fire protection renovations done the 80's used Halon systems. In modern day fire protection design standards, halon systems are now outlawed due to the contaminants that are present in the halon mixture. To prevent any environmental impacts the use of this type of preventative measures were banned. The Vizcaya in Everglade City, Florida, used Halon to protect its valuables. "In all, Vizcaya utilized 26 186 lb. tanks, six 340 lb. tanks and five 33 lb. tanks with approximately 1,000 feet of piping." (Firewatch Vol. 4 1985) In this mansion, Halon canisters where placed in conveniently hidden places for example behind walls and doors and in unused bathrooms to keep the system as invisible to public sight as possible. It was also essential to not tamper with the existing structure in any way or even the internal environment of the mansion. The sight of canisters would greatly decrease the value and disturb the atmosphere of the historical mansion. This was the obvious choice for the mansion was because of the rare paintings, murals, an extremely valuable organ and the rare book depository. The building protected "a rare book depository, a 6,000 square foot old mortgage record storage center." (Firewatch Vol. 4 1985)

With all of these unreplaceable items and the greatness of water damage, a fire a Halon system was the obvious choice for this building and for the codes of the era. For an identical situation today a dry system or elaborate sprinkler system with areas that contain valuables for example vaults, these places would use a dry carbon dioxide system. This system has no harmful environmental impacts but it has some life safety impacts to consider. The carbon dioxide system would prevent any water damage to the antiquities as well. Thus providing this building with up to date and code abiding systems.

Halon systems were also included in the upgrading of Mount Vernon fire protection, once again not wanting to destroy or ruin any of the historical artifacts that are in the colonial mansion. The fire protection system also included a nearby 1,400 member volunteer fire department and also a "11 members of the Mount Vernon Estate Fire Department, a volunteer brigade..." (Heuval) to respond to any flaming misfortunes that may occur on the estate of one of our country's forefathers. Several of these members are residents of the estate and are always on duty to protect the mansion. These volunteers train for the worst cases with the Fairfax County Fire Department. The department deals with "...fires, suspicious characters with packages, everything." (Heuval) that can happen in historic Mount Vernon, Virginia. The owners of the colonial mansion were concerned with fire dating back to 1858 "when it installed cisterns and force pumps." (Heuval) The Mount Vernon Ladies' Association also wanted to keep their fire protection systems up to date. "In addition, they felt that modern fire protection systems and devices should not intrude on visitors' appreciation of Mount Vernon." (Heuval) With these ideas in mind, a system that did not distract the overall feeling of Mount Vernon which protects the entire mansion was installed using the Halon 1301. "The separate systems located in the house use a maximum of 220 pounds of liquefied gas for the large banquet hall, and the least amount, 10 pounds, to protect the cupola. As estimated today, it would cost $100,000 to replace the halon and recharge the systems if the halon were dumped." (Heuval)

Mount Vernon also used smoke detectors in the ceilings of all floors. However, all of the smoke detectors on the first floor are recessed and have a vacuum to draw in fresh air at all times. The volunteer fire fighters were trained vigorously to quickly and reliably extinguish any fires that may occur. The training also included salvage procedures and life safety precautions that may be needed in the time of a fire. Mount Vernon also has its own fire engine "Big Red" which stores 500 gallons of water so it can be quick on the scene. Now a days the "Big Red" may also be called historic dated from 1968. Mount Vernon has security guard manning the control board at all times. The security board includes all the fire sensor controls and the pin point location grid at all times. This enables the trained personnel to pin point the fire and dispatch the fire fighters promptly and accurately

At the Winterthur Mansion in Wilmington, Delaware, the entire estate was updated to the modern fire codes. The historical site dated back to 1839 and since then many buildings were added to the grounds and expanded the complex. The Winterthur collection ranges from a rare book collection to valuable paintings. The estates old fire protection system was a high voltage detection system that was still operable and has been maintained and serviced during the time of the renovating. "Wiring the museum for life safety is an electrician's nightmare. Because there are many rooms within rooms, the wall you see is not necessarily the real wall and the ceiling may not be the real ceiling." (Cash) Thus creating a new problem for the life safety designers. "The main museum building, expanded by Du Pont in 1929, was solidly constructed. No expense was spared, and plenty of heavy concrete was poured. These factors make changes to the structure physically challenging." (Case) The new system that was to be installed in the building complex was to be installed backwards because of the complexity of the system and the structurally soundness of the building. In addition to the early response system that it has the Winterthur mansion also has an 18 member staff"...who are trained in the special techniques required to fight museum fires, Winterthur has its own aerial apparatus and two pumpers. (Case)

The new system for the site is the modern more sophisticated microprocessor-controlled detection system and in some areas of the building used in addition to the preexisting halon suppression systems. The architects chose this protection system because of the largeness of the site and the quick reaction time of the system. This system is very easy because you can have complete control over it and also the system is run into a central control station, which houses the main controls for the fire and smoke detection systems in the complex. It is also very easy because you can pinpoint the exact location of the fire and in what building and how to respond to the situation in record time. The newly designed system also brought the Winterthur complex more flexibility with there control system. The user can make up to two hundred changes to the system's preprogrammed memory. Extra loops can be added when needed.

The installation of the system had to be completed in a "backwards" type of manner. The head end equipment was installed by first. "A four-person crew spent 2 months building a riser and getting the head-end gear, the command module, and two control panels installed and running." (Cash) Upon completion of the backwards installation, a complete operating control system was created before any of the alarm initiating and indicating devices were installed in the building. In addition to the alarm detection systems, the Winterthur complex also improved egress, panic hardware, and emergency signs. "The result of this backward approach is not only great flexibility, but immediate protection." (Case)

In Toronto, the Ontario Legislative Assembly Building was opened on April 4, 1893 to house the seat of government for the Province of Ontario, Canada. "It is a grand, five-story, stone structure accommodating offices and the Legislative Chamber and was built to serve the people of Ontario." (Muniak) Although the building is only one hundred years old it is called a very important heritage structure of the country. The building also contains some historical records of the development of the province and its social growth. A fire in 1907 destroyed the west wing of the building. The west wing was rebuilt using non-combustible materials. This was a start to fire protection in the building but the rest of the building (east wing and the center block) still consisted of combustible materials. Other construction that followed included compartmenting of the building and improvements on several staircases. " All of these changes had a positive effect on fire and life safety in the building but a negative effect on the original architecture and the historic fabric of the building." (Muniak)

"It was accepted and understood that the building fabric, the compartmentation, the mechanical systems, as well as active and passive fire safety systems, would need to be designed to control fire anywhere on the premises." (Muniak) Tests were performed to find the fire resistance of the building and a relatively good approximation of the various ratings was determined from the studies. Air movement analyses were conducted because of the open design of the building. "This information was used to plan exit paths and strategies for re-compartmenting or opening the building." (Muniak) In designing a protection system it was known that all the concourses and corridors that are used by the public need to be clear of smoke should a fire occur. A number of people would be using this route to evacuate the building in the time of need. An entire rework of the egress of the building was completed. It was argued that a wet system should be used in the building and it was concluded by the governing authorities that the system be a wet one.

The National Gallery, in London, contains some of England and the world's greatest paintings. The gallery was housed in a building on Trafalgar Square in London. Today it houses over 2,300 pictures. 1991 was the opening of the Salisbury Wing of the complex. "The total gross floor area of the Gallery is now 41,360 square meters providing 68 galleries and seven temporary exhibition galleries." (Catchpole) The Gallery handles about 9,000 visitors a day in the building.

One of the protection areas of the building included evacuation of the 9,000 people that is can have in a day. The existing plan includes a single-phase where everyone evacuates the building once an alarm sounds. That plan is being thrown away for a two-phase plan. To improve the protection "fire shutters have been installed in the doorways linking the old and new wings of the Gallery which will create separation in the event of fire." (Catchpole) The fire protection system is further improved with the addition of "warders in every room and 24-hour security patrols." (Catchpole) During the evacuation process theft is also a concern for the Gallery. The staff is trained to be sure of the exit of all patrons during an evacuation. In case of theft the Gallery has the ability to lock all the doors of the Gallery if an item is stolen from the Gallery.

Other security measures that are found in the Gallery include, CCTV, devices on pictures and card access into private areas. All the monitoring devices, for example, door closers, beam detectors, point-type detectors, are wired to the buildings fire and security system. In the building the combustible materials were kept to a minimum with an open floor plan. "A fire and security committee meets regularly to refine contingency plans." (Catchpole) To this date "a new addressable fire detection and alarm system has been installed and a wet-pipe sprinkler system now protects high-risk areas such as the framing shop, frame store and the loading bay. Since the size of the building and the evacuation distances exceed code regulations, additional fire protection measures are to be installed in some staff areas. Work includes creating lobbies at the base of each escape route and installing fire doors and corridors of protected areas. Another risk that was assessed and remedied was the electrical systems of the Gallery. Resulting in a complete rewiring of the entire building of the Gallery.

"The Wilkins building control room is protected by a halon system and an air sampling system." (Catchpole) The control room for the Gallery handles 2,000 devices which are subdivided into 115 zones, located in protective positions in the building. "When a device is activated a recorded voice message sounds throughout the building, alerting staff and visitors that a fire situation is being investigated. Staff have five minutes to check the location of the device and clear the panel - if the time limit is exceeded then the bell sounds to evacuate the building." (Catchpole) This prevents the Gallery from any false alarms and release of the wet system if not needed for the situation. The Gallery also has a backup control room in the Salisbury Wing of the Complex.

The historic Bank of England, which is over 300 years old, and it has been located on Threadneedle Street since 1734. Many of the extravagant architectural features of the building have been preserved throughout the times. In the early eighties, the building was renovated to update the building on its fire protection equipment and systems. The pressure and suction shafts of the building were replaced with electrical risers and included in the newly installed electrical risers were fire detection equipment. Also, 150 point-type detectors were installed in the electrical rooms, fan chambers, and in the plant services rooms. The bank's interior design system was not altered during the retrofitting of the protection systems used in the library.

In 1986, the Bank of England invited proposals to be submitted on the fire protection improvements of the building. The proposals of the building like all others must not interfere with the internal environment of the building. "The building currently comprises a basement, sub-basement and seven floors above ground. In designing an effective fire detection system, the company was constrained by a number of factors; of these, the actual bricks and mortar presented the greatest challenge." (Cerberus Limited) The construction started in 1989 and the fire doors on the stairwells were upgraded. The basement area of the building was improved with fire closers to any spread of fire in the lower levels. Automatic smoke detectors have been installed throughout the building to prevent any smoke damage of the valuables and any money that is present in the bank. The system has a very early warning of fire because of the sensitivity of the sensors and placement of the smoke detection sensors. An air sampling system was install to check the air for any discontinuities in content. Thus, any discontinuities would result in the triggering of the alarm. "Complete Compatibility between the air sampling systems and the main fire alarm system involved linking the air sampling system into the central control unit." (Ceberus Limit)

Also, the system has a very low frequency of false alarms. This provides quality assurance to the system now. There will be no second-guessing the system. A satellite control unit to a central control panel links each detection device installed in the building where trained personnel are watching the switch board for any emergency's that may occur. The control room along with the trained personnel gives the building constant protection against any misfortunes. The central control center will have the precise information on the exact location of the fire if the alarm is activated. The personnel in the control are train as to correct procedures that need to be performed at the time of an emergency. The building contains many rooms with a high vaulted ceiling and in these rooms small rectangular boxes 112mm x 180mm were installed on the walls of these rooms. These boxes were mounted on the wall and positioned so that a pulsed infrared beam can be sent from one sensor to the other making an infrared gird below the ceiling area. The infrared sensors are programmed to react to any change in the beam or grid, which in result would set the alarm off. The sensors themselves are virtually invisible from the floor when installed onto the wall of the complex.

The Bank of England also includes a museum in the building. The museum was also included in the fire protection proposal of the Bank. The museum contained a smoke detection system was installed in each of the museum displays. In the displays, the smoke detection units are made up of a two-chamber metal housing with a built-in ventilator. The device inhales air into a tube where the smoke is analyzed, when smoke is detected it is sent via satellite to the control center and the alarm is sent off. Along with the detection units, 166 break-glass points have been installed throughout the building. These devices are activated when the glass of the displays is heated to the point where they break causing alarm activation. The alarm, when set off, has a voice evacuation program to use in sensitive areas during evacuation cases meaning that in areas where tourists are abundant a voice will tell the tourists to please exit the building promptly. Sounders are located in the rest of the building's rooms and corridors, which are not as sensitive.

The systems are all controlled from the fire control center, which is located in the security control room and is similar to the control center of the Bank. A host computer in the security control room receives information from the eight satellites control units located throughout the building. At the control room, fire officials at the switchboard evaluate the information and react to the given situations. Security officials are in the control room around the clock evaluating the information that is received at the control. Since there are personnel working day and night there is no need for automatic operation in the museum complex.

These systems installed in the Bank of England and its museum are very crucial to a fast response system. The information is fed to the control room and then must be reacted on by the working personnel and reacted correctly. To solve that problem the personnel must undergo hours of training to man the panel. The systems themselves keep the atmosphere of the building intact and provide adequate protection for the historic building and the museums' artifacts. However, the protection systems contain adequate smoke detection system but there was no sprinkler or extinguishing system to the fire protection system. The extinguishment system was dependent on the manual fire suppression of the fire department.

The George IV Bridge building is over 300 years old and contains over 6 million of Scotland's heritage books. The building was also the winner in Category I of the Fire Protection Association's top fire safety awards. Protected in the building are several maps, music, newspaper and books. Surveys were performed in 1988 on the building's fabric and services. From this, work was found to be needed on the building envelope, reconstruction of the structural stonework, and reconstructing the roof system. "Work recommended for the mechanical and electrical systems involved replacing heating, chilling and air-handling plant, together with new pipework, valves and ductwork. The electrical work included complete rewiring, replacement of the fire detection and alarm system and new lifts." (Lee) Dr. Eric Marchant of Edinburgh University's Department of Fire Safety Engineering and Rex Wilson of Firepro Inc. were hired to appraise the building. Their findings found no smoke detection system what so ever. The fire detecting and suppressing systems, emergency lighting, and escape paths were inadequate for the building's size and population. They also noted that fire fighting would be very difficult in the building due to the heights of the floors containing the bookshelves contrasted to the heights of the surrounding office floors. Some routes to the rooms were so elaborate that fire fighting would be dangerous and difficult.

Another fire problem in the building, is the question of structural stability in the building if it is on fire. The fire can cause certain members of the floor system to expand and deflect to the point of collapse. The report proved that ".. .the structure, while sound under normal conditions, could be susceptible to collapse in the event of a fire." (Lee) The structural problem consists of several different things. For one the concrete flooring although it has the appearance of being steardy they are actually very thin and are supported by the floor beams but also by the stack shelving system in the library. From this a structural analysis was needed to determine if the framing system could withstand a fire and for how long. The steel used in the construction of the building was 14 gauge steel that was folded into square hollow tubes and this offered no sort of fire protection for the building's steardiness. Also, the amount of reinforcement in the concrete and the steel in the intermediate floor systems was also inadequate to provide any stability in the building. The only fire resistant members in the building were the columns and the beams. The shelving would collapse at a temperature a fire can produce in ten minutes. This collapse of the shelving units would progressively lead to the entire collapse of the structure since the flooring system rest on the shelving units. Two escapes stairs were installed into the library. One was built near the special collections area of the building and the other escape staircase was installed near the library offices and workshops.

The renovations performed on the structure were accomplished while the library remained open to the public. Since the library remained opened the workers not only had to keep the buildings historic environment intact, they had to perform the work cleanly, low decibel of noise, and structurally secure. Recommendations for the renovations included removing the intermediate floor systems and installing a new book shelving system. The floors then had to be replaced with structurally sound and fire resistant flooring materials. One of the most important problems was to take the loads away from the shelving systems in the library and transfer the loads to the beams and girders of the building.

Dr. Marchant made recommendations for a smoke detection, a smoke control measures, and a fire alarm system be installed. New escape routes to serve the reading rooms and mezzanine levels of the library were cleared and marked for the library. The library did not want the problem of high-pressure hoses destroying any of the books and artifacts in the building. To remedy the situation a full automatic sprinkler system was recommended to protect all areas of the library. With the addition of the system, risers were installed to assist fire fighters during a blaze. The sprinkler zones were designed with regard to the fuel in the zone, function of the room, value of contents, and the structural sensitivity of the sprinkler zones. The sprinklers would be programmed to tell personnel of the exact location of a fire. "It can also be argued that dry-pipe systems should generally be avoided because they tend to be less responsive and more expensive to maintain. Due to the greater delay before water is discharged, the fire is likely to have developed to a greater extent than would be the case with a wet-pipe system and therefore more water would be required to put out the fire." (Gibbon) The library is currently reviewing their additions and will revise any changes if needed. The total cost of this project was ten million pounds and that cost would be a fraction of the cost to transport, store, and hold the books and materials at a storage facility.

All of the existing fire doors were replaced with two-hour fire-rated doors providing extended protection to those unfortunate to be in the blaze. The staircases and elevators were pressurized to prevent them from being smoke filled and potentially dangerous to fire fighters or evacuating readers. Improvements also included emergency lighting, removal of incompatible items for the stacks, and a relocation of the computer room. Besides the structural overhaul and fire protection improvements of the library, the staff will undergo intensive safety training course arranged for the life safety off all occupants and procedures to perform in the time of need.

Building retrofitting was a tedious and ongoing design for these buildings and also those responsible. All of these buildings, also needed different needs to be accounted for and different structural systems to design around. To fully retrofit a building for life and fire safety it must be analyzed over and over again. When that stage is complete it must be done again. When the building is completely protected there may still be small problems that are left unnoticed only until after an incident occurs will it be fully noticed to the designers. An actual fire is the best test for a protection system and this is never wanted but fires are awaited. These buildings have been fire protected and are prepared for emergency situations that are presented to the building and its personnel. Once again the final test will show if the designs and retrofits have accomplished what the systems were designed to do and perform to the levels anticipated.

The British Library is a great example for modern fire protection design and also retrofitting. It was first designed, built, then due to faults in the installed system it had to retrofitted with a new improved system. The library used design methods for construction of the building and also retrofitting methods to accommodate the constructed building and its limitations. The library is combines many unique systems that prevent fires and also have a different impact on the buildings environment. For example, the wet sprinkler systems would drown the fire, while the carbon dioxide systems would to an important ingredient for fire out of the air. These systems have effects on the buildings environment that could destroy or save the artifacts. Although dry systems are ideal in some instances wet sprinkler systems are the optimum choice for protection.

The National Gallery in London, England, contains some of England's finest paintings and artworks. It contains a combination of fire protection and theft protection in the systems. Both systems work hand in hand to prevent any misfortunes, for example theft or a fire. It was wise to a fire protective materials due to the fact the building is so large and it has a extensive evacuation time. The wet-sprinkler system can be questionable due to the fact of water damage to the paintings if a fire occurs. The Halon system in the control room gives the control room protection from water damage.

The Scottish Library is an award-winning example of fire protection. The design and analysis took time to complete but it was worth making this national historical building able to withstand and safe materials during a fire. The vast improvements on the building gave it structural strength and also it gave the building the personnel to handle situations which fires are present and ways to fight the fire and protect the heritage that is contains in its shelves.

The original high voltage system itself was deteriorating and too small to operate the entire complex's protection systems. The Winthur Mansion's proprietors saw the need for a new protection system that could save the complex in the time of need. For a complex of that vast size the microprocessor systems is a great choice because of the quick response time of the system. The new system also provides a more flexible usage for the addition or reconfiguring of the system.

The Vizcaya Mansion uses the now illegal form of fire suppression, halon. The mansion has many spaces which are occupied by halon canisters. For the time of construction the halon system was the best case preventative for the protection of the mansion. The installation company was very professional and completed the fire protection project with virtually not trouble with the design.

Mount Vernon is also a fine example of the fire protection industry and its history. With the early protection ordered by the wives society that ran the building, the fire protection in the mansion was unique to its time. Now a days there is a fire department on site with several volunteer fire fighters. The mansion is also updated with more modern techniques used by fire protection engineers which were rarely hard during colonial times.

The Toronto Assembly building contains some of Canada's most historical treasures. The building was also a fire trap. The new building that was added to the Assembly building was built of fire retardant materials but the other section of the building was made from combustible materials that could disasterous to the structure in the time of fire. The compartmentation redesign and fire protection upgrades were crucial to this building and were done so to keep the buildings interior fabric intact.

The George IV building in Scotland holds many of Scotland's oldest books and written materials. This building hold to be structural upgraded to withstand fire temperatures and to have structural stability. The fire protection system was also redesigned and housed many different components. Which was integral to fire protection in the building. This system suited the George IV building adequately.

The bank of England, which was also a museum contained many historical works of England, was desperate for upgrades on its building protection. The protection systems were installed to give the Bank a cutting edge on fire protection and also theft protection. The overall evaluation and redesign was unique for the Bank. The fire protection plan also included theft protection and the theft protection had ties to the fire protection system. The overall protection system for the building was very well designed and suited the building remarkably.

The Smithsonian Institute has many buildings under its supervision and tries to protect its buildings with the utmost protection that its resources can provide. The Castle and Getty Center are prime examples of the Smithsonian. Both buildings were provided with superior designs of fire protection. Which were the best fit protection systems that could be provided to the buildings.

All of the buildings and systems discussed were designed to give each individual building the protection that it needed to protect itself from fire. These designs used the best materials of the day and era, which the protection materials change with time too. For example halon has since been outlawed after being a major component to fire protection. Now carbon dioxide systems have taken place of the halon systems. All components to the system are vital and so is the combination of the building's fabric and fire protection design.

Utilities of Fire Protection

There are a multitude of options when deciding on a fire protection system to safeguard any building. The most important point to consider when choosing such a system is what are the specific things you are trying to keep safe and what might do the most damage to the items. For instance, the main concern for a museum like the Boston Museum of Science might be life safety over artifact preservation due to the heavy amount of human traffic in the museum at all times. This however might be not so high on the list for an archive with irreplaceable material and few people there at any given time. The Worcester Armory falls into the latter category.

Smoke and fire detection systems are usually the first line of defense in any building. These "smoke detectors" come in a variety of designs and are used to detect different aspects of common fires. Fire produces byproducts that can be used by detection systems as triggers. All fires produce aerosols, vapors, and gas. Aerosols are tiny particles suspended in the air. When a fire burns, it gives off these aerosols in the form of soot or droplets. Vapors are gases that result from the overheating of an object. An example of this is the shimmering column coming from a lit candle. Gases are the result of a chemical reaction that defines combustion. The most common gasses given off are CO and $C0_2$.

Heat detectors are one form of detection system. These detectors measure the amount of heat transferred to the ceiling of an area by convection. These detectors are usually divided up into two groups, point sensitive and linear sensing. Point sensitive detectors are small units that respond individually to an increase in heat. Linear sensitive detectors sense heat across a continuous surface. Some different methods used in these units are melting metal, a liquid inside a glass tube (meant to burst), a strip of plastic, a bimetallic switch, or a pneumatic switch. Most of these heat detectors are the ones found in normal sprinkler head and act as activation switches for water flow.

Smoke detectors are another general class of fire detection devises. They are split up into four groups: Light beam detectors, Ion chamber detectors, Photoelectric/light scatter detectors, and aspirating type smoke detectors.

Because light beam detectors have been in use for a long time, they have been refined and made rather reliable. The idea is to shine a beam of light across an open area onto a receptor and measure the amount of obscuration in the air. Today, lasers are more often used as the source and have a low bandwidth and high accuracy. These systems have several constraints associated with their proper functioning, however. Alignment of the beam must be maintained and could be subject to vibration of the object on which it is mounted. Also, insects, birds, mist, and dust might be troublesome to the desired operation.

Ion chamber smoke detectors use a very low voltage produced by a radioactive source to determine what types of particles enter the sensing chamber. The radioactive element ionizes air particles and creates a current that spans across the sensing chamber. When smoke particles enter the chamber, they attach to the ionized air particles and, by increasing their mass, slow down their movement. This corresponds to a decreasing voltage across the chamber which is measured by an electronics package on the receiving end of the circuit (see figure 1). The activation voltage can be adjusted for the situation and is used to measure particles of combustion that measure one micron or less.

Photoelectric smoke detectors use the light scattering properties of smoke particles to detect fire. A light source (usually LED) is shown onto a receptor which measures the amount of obscuration by the particles. See figure 1. These detectors are useful when large particles, such as those found from burning plastics, are prolific. These detectors are usually sensitive from about 10% obscuration per meter.

A relatively new addition to smoke detectors is based on the photoelectric sensing system and is usually referred to as an aspirating type smoke detector or by its trade name, VESDA®. Air is drawn into a sampling chamber by fans where a xenon flash tube is used to obtain a measure of the obscuration. This system is up to 300 times more sensitive than conventional photoelectric smoke detecting systems. The active air sampling reduces response time considerably and the system is sensitive for obscuration levels of .01% per meter. (Figure 1)

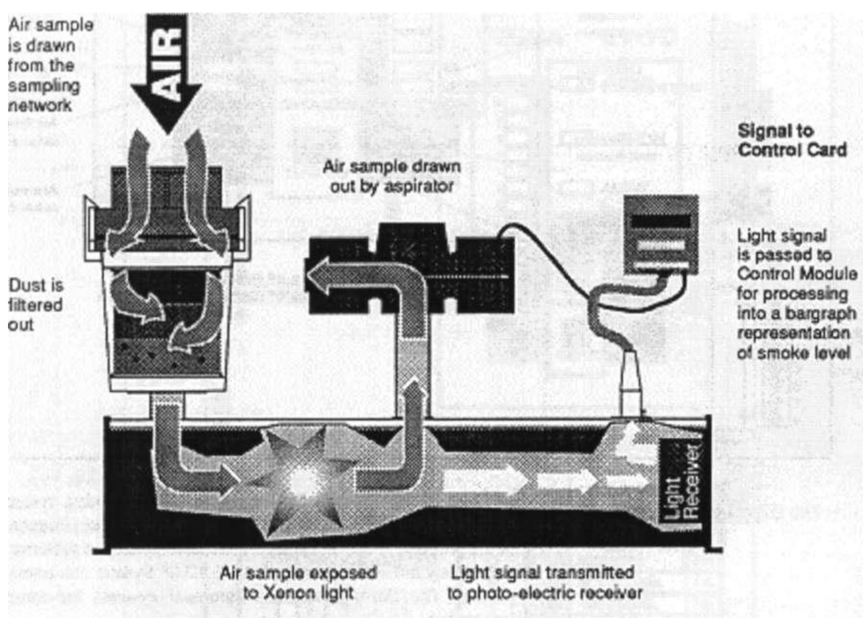


Figure 1

Radiation/flame detectors do not sense the products of combustion, as do the four types mentioned above. These devices detect the light radiation produced by a fire. This decreases the time required for detection but is not as reliable as any of the other systems discussed. This lack of reliability is due to the many other sources of light radiation common to our environment. Common false radiation sources are the reflection of the sun off of the hood of a running car or lit candles on a birthday cake. One major characteristic of radiation coming from flames is the flicker. The modulation of the car hood or the flickering of many different birthday candles falls into the common range of flame flicker. Designers have been successful, however, in overcoming many of these obstacles. There is a region of wavelengths of light usually absorbed by the earth's atmosphere. This region is used as the detector region. Also, more than one spectral area can analyzed and the data cross-referenced to greatly increase reliability.

Testing has shown radiation detectors to activate in 5-10 seconds to a liquid fuel fire. As with most of the detector types, these devices can be very useful for specific applications and conditions.

Table 1 compares different detection systems with respect to their area of coverage, response time, and fire size necessary to activate the system.

Heating, ventilation and air conditioning (HVAC) systems are used in most buildings to some degree. These systems can have large effects on the growth, spread, and life span of a fire. They can also greatly effect evacuation and fire fighting procedures. The forced air movement of ventilation systems can accelerate the spread of smoke and heat. This might transfer smoke into remote parts of the building and increase damage or trigger unnecessary sprinkler activation. If an HVAC system is designed with fire safety in mind, it can have very positive affects in controlling the amount of smoke damage to an area. Correct configuration of fans and duct closings will channel the smoke out of the building and create a positive pressure inside selected areas. Smoke clearance systems are designed to do exactly that. They contain smoke in a safe chamber, keep it there with smoke screens, and then extract it from the building using smoke extraction fans. These systems usually included in buildings that have significant life safety problems and are only active in the event of a fire. Some examples are shopping malls, atrium structures, and concert, convention or sporting centers.

There are many regulations involving smoke extraction systems. The location of extraction areas is critical to removing as much smoke as possible and not just sucking clean air out. For this reason, extraction points should be evenly spaced throughout the area. Fan sizes and speeds are designated according to the size of the effected volume and the pressure loss to the room that the smoke is being extracted from. The fans and adjacent machinery should be able to operate at the elevated temperatures that the smoke will conduct. The policy for how long a fan must be rated for in the United States varies from state to state but falls somewhere between 260° and 650°F for a 1 hour duration. Adequate clean air must be provided to offset the pressure difference created by the outflow of the fans. This inflow must not disturb the smoke in the containment chamber and must not re-circulate contaminated air.

The most common active fire suppression system is an automatic sprinkler system. This system is composed of a network of pipes and discharge heads that deliver water locally to a fire. These sprinkler systems come in many types including dry pipe, wet pipe, pre-action, and deluge to list a few. The discharge heads are made with a heat detecting device that opens the water flow in the event of excessive heat. This heat detecting devise is commonly a metal link or a glass bulb. In the event of the required temperature being reached, the bulb breaks or the metal deforms and opens the valve that allows the water to strike a deflector of specified geometry. See figure 1. The temperature at which the head activates can range from about 55°-250°F depending on the application requirements. The deflectors on the sprinkler heads distribute the water in a pattern suitable for the area of operation. Sprinkler heads are mounted upright, hanging (pendant), and horizontally.

Sprinkler system types are likewise specified for use in certain environments. Wet pipe systems contain water in all of the pipes, all of the time. This is advantageous as it permits fast response to a fire. This system is most common and is suitable for all environments where the temperature does not fall close to freezing or rise close to the vaporization temperature of water.

Dry pipe systems are fitted with gas in the water pipes that discharges through the open head and allows water to follow. These systems are used in situations where there is the danger of stagnant water to freeze and disable the system. The response time is greater due to the delay of water to the extremities of the pipe network.

Pre-action systems are a compromise between the two systems outlined above. In a pre-action system there are two detectors which are rated at a different sensitivity. The more sensitive detector sends a signal to the control valve of the sprinkler system or specific region that fills the pipe with water. The second detector opens the valve on the sprinkler head and discharges the water. Because of the complexity of these system types, they may be less reliable than the previously described types. The main advantage of pre-action sprinklers is the added security against accidental discharge. The system requires two detectors to be set off before discharge of water.

Deluge systems are used for areas that have the possibility of rapidly growing fires. Materials like aircraft fuel, explosives, and dust or gasses have a high rate of combustion necessitating this design. The deluge system is a dry pipe system with all sprinkler heads permanently open. A heat detector sends a signal to open the system control valve and all of the sprinklers discharge at once. Also available on any of these sprinkler types are automatic shutoff systems to prevent water damage to an area where the fire has been suppressed.

Mist

When water mist droplets contact the surface of hot or burning substances, the water droplet changes from a liquid to a gas (steam). This transformation absorbs tremendous energy from the surface of the combusting material. Water expanding into steam increases in volume 1,760 times. The expansion removes heat from the burning fuel so as to lower its temperature below the ignition threshold. Further, the droplets and steam impinge on the surface of the fire to create blanket in which the fire quickly depletes its supply of oxygen.

The key to the success of a fine water spray fire suppression system is the ability to generate a directional mist or fog of fine water drops through the nozzles. The nozzle design must produce a small droplet with an orifice sufficiently large to avoid clogging from suspended particulates that may be present in the water stream.

Liquid water and pressurized air are mixed in a turbulent motion in the mixing chamber to produce and deliver a spray of water mist. The optimum water droplet size ranges from 80-200 microns of mean diameter. The droplets must be small enough to penetrate all areas behind obstructions, yet large enough to penetrate to the surface of the combusting fuel.

Only very small amounts of water and air are needed to extinguish even the most intense fires (including gasoline fires) because a small amount of water is effectively spread into fine water droplets covering a large area. Many industrial plants have pre-piped supplies of compressed air throughout the facility. In these cases plant air is substituted for compressed air stored in dedicated cylinders. The water contained in the storage vessel can be de-ionized and treated to comply with current health requirements and can be pre-mixed with commercial-grade foaming agents to provide even greater class B fire extinguishment.

In certain applications water mist compares favorably to other fire suppression systems.

Traditional Sprinkler Systems Fine water spray fire suppression systems extinguish fires more effectively and in scenarios exceeding by far the capability of traditional sprinkler systems. Water deluge systems demand high water supply rates and are associated with fixed large bore pipe networks around the protected area. Unlike deluge systems, fine water spray fire extinguishing systems use very small amounts of water and therefore only require small bore pipe networks.

Carbon Dioxide- Unlike Carbon Dioxide, water mist does not remove excessive amounts of Oxygen from the protected area, nor is it toxic upon inhalation.

Halon 1301- Unlike Halon 1301, water mist is not a controlled substance with known Ozone depleting properties. The recharge of a water mist system is inexpensive compared to Halon 1301. Room sealants are not as much a concern with water mist systems.

Inergen and FM-200- Neither of these agents pose environmental dangers and both offer substantial advantages when protecting data processing, telecommunications, and other electronic equipment facilities. Water mist does feature the ability to provide local application protection where total flooding is not possible because of structural configurations.

Foams

A fire fighting foam is defined as an aggregate of air filled bubbles formed from an aqueous solution and having a density lower than the lightest flammable liquids. These foams act to smother and/or cool a fire and there by extinguish it. As a blanket is formed over the burning surface air is excluded and vapors rising from the fuel are suppressed to exclude the possibility of re-ignition. Most fire extinguishing foams are used for fluid fuel spills such as are often found in aircraft hangers or in flammable liquid storage areas but new systems and types of foam are being used in forest fires and residential and commercial structures. Foam for these hazards can be supplied by piping systems, or by foam generating systems. It may be applied through foam discharge outlets, which allow the foam solution to fall on the surface of the burning fuel. Portable hose streams with foam with foam nozzles can also apply the foam solution. This is in fact the only suitable means of extinguishing large storage tank fires because of the buoyant and blanketing effects of the solution. Tests have been conducted that show that compared to water foams have a longer ignition time when used as a treating agent and a faster fire suppression time. Foams also have an expansion of 20 tolOOO times initial volume. This feature reduces the amount of water needed to fight a fire and is ideal for reducing the cost of sprinkler systems.

The concept of using foam as an extinguishing agent was first realized in the 1930's. It consisted of a proteinaceous-type liquid foam forming concentrate but was limited in applications due to the lack of mobility of facilities and cost of mixing and regulating apparatuses. In 1957 the first foam overhead sprinkler was designed but was still relatively obscure. The Texas Forest Service developed Compression Air Foam Systems (CAFS) in 1977 that revolutionized the product and made foam agents more appealing to the fire protection community. The concentration of all of these foams was usually three to six percent by volume of foam concentrate to water. This was standard until Canada came out with a synthetic surfactant foaming agent in 1985. The concentration levels per volume in this foam are decreased by a factor of ten to .3 to .7 percent. Most common foams now are used in concentrations of .3 to 1.0 percent by volume. As foam is more widely used as a suppression agent and more research is funded for the development and advancement of this class of materials costs will continue to drop and applications will increase in number.

Five general types of foam are now recognized by the NFPA:

Protein-Foam Concentrates- This foam uses protein hydrolysis plus some additives and stabilizers. They are normally used in concentrations of three to six percent.

Fluoroprotein-Foam Concentrates- This concentrate is very similar to the protein-foam but adds a synthetic fluorinated surfactant. This additive allows the foam to form a vaporization-preventing film over the fuel source as well as excluding oxygen from the burning surface. Concentrations are three to six percent by volume.

Aqueous Film-Forming Foam (AFFF) Concentrate- This concentrate is based on a fluorinated surfactant and forms an aqueous film on the fuel surface that suppresses surface vapors. Again a three to six percent by volume concentration is used. This type of foam concentrate is also dry chemical compatible.

Film forming Fluoroprotein (FFFP) Foam Concentrates- FFFP's use fluorinated surfactants to form an aqueous film that inhibits hydrocarbon vapors and is highly resistive to fuel pickup. This type also uses a three to six percent by volume concentration.

Any type of foam is not considered an appropriate extinguishing agent on fires involving liquid or compressed gas. For example, some of these gasses are butane, butadiene, or propane. Foams are also not suitable on materials that react with water violently, such as metallic sodium, or on fires involving electrical equipment. Foam concentrates cannot be used on fires in water-soluble solvents or polar solvents. There are special "alcohol-type" concentrates available for the production of foam for protection against these types of hazards.

Alcohol-Resistant Foam Concentrates- These types of foam are used to fight fires whose fuels are water soluble, hydrocarbon involving or are otherwise unsuitable for FFFP's or AAAF's. There are three types of these foams

-water soluble natural polymer based (proteins, fluoroproteins) these form a wall that is impenetrable to alcohol based materials.

-synthetic concentrates (felling) form a gel around the bubbles to protect them from water soluble materials. This agent may also contain film-forming characteristics for use against hydrocarbons.

-natural polymers and gelling: A hybrid of the two aforementioned alcohol resistant foams. It utilizes characteristics of both types.

The uses of foam for means of fire protection have increased intensely since its first application in the thirty's. The original use of this agent used a proteinaceous-type liquid foam forming concentrate in a water solution to a turbulence foam generator or nozzle. This then directed the foam to a burning fuel tank or area of the burning fuel. A new technology was developed over the years, new fire protection systems and devices for applying the foam were introduced. The application of foam from sprinkler systems was developed early on in 1954. Now, there are four main types of discharge devices which are installed at the outlets of the systems. There are *foam-water sprinklers, foam-water spray nozzles, non-air-aspirated spray nozzles,* and *standard sprinklers.*

Discharge Devices **(Fig. 5)**

The foam-water sprinklers are open type air-aspirating heads which consist of an open barrel body foam maker with a deflector at the end. This deflector shapes the pattern in which the foam will be dispensed from the system. Foam-water sprinklers discharge the agent in patterns comparable to that of standard sprinklers. The foam - water sprinkler system is connected by pipe to a source of foam concentrate and also to a water supply. The piping system is connected to the water supply through a control valve which is usually activated by an automatic detection system. When the control valve opens the water flows into the piping system and the foam concentrate is injected into the water. Therefore, the foam-water solution discharges through the discharge devices and distributes the foam. Once the foam concentrate is used up the water will continue to flow until it is manually shut off. Sprinkler systems that have been transformed to use aqueous film forming foam or film forming fluoroprotein foam are classified as foam-water sprinkler systems. (Fig. 4 & 6)

Foam-water spray nozzles are also air aspirating discharge devices. However, they differ in design form the foam-water sprinklers in that they distribute the foam agent in a special pattern depending on the nozzle. The foam-water spray nozzles combine a foam maker with a deflector. These will generate foam similarly to that of the foam-water sprinklers when supplied with foam solution under pressure. The foam-water nozzles are available in numerous different patterns with differences in discharge capacity.

Non-air-aspirated devices are directional spray nozzles similar to the foam-water spray nozzles. Standard sprinklers are non-air aspirating. When supplied with aqueous film forming foam, air-foam solution, or film forming fluoroprotein, a foam discharge pattern is produced which is close to the plain water discharge pattern.

The principal purpose of the foam-water deluge systems is obviously the extinguishment of fire. The discharge rates should be proper according to the design of the system. These systems may also be operated manually to prevent ignition of fire. These systems can be operated manually to discharge foam or water in case hazardous materials accumulate from spills in such places as garages, aircraft hangers, petrochemical plants, etc. This will account for protection against ignition of these hazardous materials.

Operating Systems

The piping systems which house the foam concentrate must be of a material that is compatible with the particular foam being used. The fittings of the pipe system must be of a specific type approved to the fire protection systems. The pipe and pipe fittings should also be designed for the precise pressures involved in use, but not less than 175 psi cold water pressures. Ferrous fittings must be made of steel, malleable iron or ductile iron in dry sections of pipe that is exposed to possible fire, or if that section of pipe is self supporting. In sections that require galvanized pipe, galvanized fittings will be installed. Rubber gasket fittings can be used to connect pipe sections when the foam-water deluge system is automatically controlled. Fire exposed areas where these rubber fittings are located must be protected by an automatic foam-water deluge system or other approved systems.

In automatically controlled systems, the detecting equipment must be connected to a device to trip the water deluge valves and other system control equipment. The foam concentrate injection should be activated automatically by the activation of the water supply control valve. Whether the automatic detection equipment is pneumatic, hydraulic, or electric the system must be provided with supervision so that failure of equipment, loss of air pressure or loss of electricity will be detected. Naturally, there must also be manual means for operating the detection equipment. The manual controls should not require a force of more than 40 pounds, or a movement of more than 14 inches to operate.

The foam concentrate pumps and water pumps must have ample capacities to meet the maximum needs of the system. To guarantee injection of the concentrates, the discharge pressure ratings of the pumps must be in excess of the maximum water pressure available under any given condition at the point the concentrate gets injected.

The storage tanks must have capacities to accommodate only the quantity of foam concentrate and the space needed for thermal expansion. A vertical riser or an expansion dome can attain the space required for thermal expansion. The storage tanks should have minimum surface area contact with air and liquid concentrates. This will minimize the possibility of interior corrosion of the tank. Outlets from the storage tanks must be located above the bottom of the tank to provide the necessary sediment pockets.

System equipment must be installed where they can be accessed easily, especially during fire in the protected area where they will not be exposed to the fire. This equipment includes storage tanks, pumps, and control valves for water, concentrates, and foam solution. Automatically controlled valves should be as close to the hazard protected so a minimum amount of piping is needed between the automatic control valve and the discharging devices.

System Types and Requirements

Self contained systems are those that have all components within the system. These systems usually have a water supply or a premix solution supply tank pressurized by air or inert gases. When the pressure is released, the system begins to operate. There are four basic types of systems: *fixed*, *semi-fixed*, *mobile*, and *portable*.

Fixed systems are complete installations piped form a central foam station that discharges through outlets to the protected hazard. Any pumps that are required are permanently installed.

There are two distinct formats for the semi-fixed systems. There is the type that has fixed discharge outlets connected to piping which travels away to a safe distance. The necessary foam producing materials are then transported to the scene after the fire starts and are connected to the piping. There is another type in which the foam solutions are piped trough the area from a central foam station. The foam solution is then piped through hose lines to portable foam makers.

A mobile system is any foam producing unit that is put on wheels and can either be towed by another vehicle or may be self propelled. These units can be connected to a water supply of may utilize a premixed foam solution. Similar to mobile systems is that of a portable system. A portable system is one in which the foam producing equipment and materials are transported by hand.

Control of Systems

Systems are either controlled manually or automatically. Systems that have manual controls should be located in an easily accessible place away from the hazard zone. This is so the controls can be operated safely in a fire emergency. Automatically controlled systems detect the fire by means of various gas or fire detection devices. The detectors activate the system by operating the water control valve or another activating device. The other equipment in the system should be connected together so when it is activated the foam solution is supplied to the foam maker and discharged.

Combined Agent System

Combined agent systems are those in which foam is applied to a hazard along with a dry chemical powder. This system combines the fire extinguishing capabilities of dry chemical powders with the sealing capabilities of foam. The application of each agent is separately controlled so that the agents may be used individually or simultaneously.

As more information becomes available fire departments around the country have tried and met with great success new foam suppression systems. Fire departments in Texas, Maine, Virginia, North Carolina, and in near by Boston have all used foams. This is in addition to The Forestry Departments in California and Texas.

Of course, as with all things there are drawbacks to go with the advantages of incorporating such systems. The corrosive effects of the foam concentrate are such that a rinsing is in order after each use of a system to clean out nozzles, hoses, seals, and caps. This will result in a slower turnout time of engines and equipment but could probably be overlooked in emergency situations. It has been estimated that the potency of the foam concentrate is about equal to triple strength detergent. Due to this corrosive aspect and also its irritating quality certain protective clothing must be worn by firefighters when administering this product. Goggles or eye protection should be worn as well as water proof gloves and leather or rubber boots. It has been recommended in MSDS (Material Safety Data Sheet) No. M00013364 that SCBA units be worn at all times to prevent vapors from entering the respiratory tract. It is also noted that drinking the pure concentrate would endanger your health. Care must be taken to have proper education and training to effectively utilize foam fire fighting systems. The pressure to the nozzle size of the hose, type of nozzle, and amount of water are very important consideration all of which will have drastic effects on the quality and properties of foam produced. In addition to the contents of the foam-water solution temperature is a large consideration.

At temperatures of less than -10 degrees Fahrenheit studies have found that the solution will disassociate and crystallize.

These disadvantages may sound discouraging and costly to many in the fire protection field but pale in comparison to the increase in suppression capabilities, long term cost effectiveness, environmental considerations, and increased safety to fire fighters. With environmental considerations becoming increasingly important in public policies a decrease in the amount of water needed to put out a fire will become more and more appealing as time passes. This decrease in water consumption also lessens the total weight of hoses allowing for easier manipulation or equipment and less fatigue to fire fighters. Fore suppression, containment, and resistance capabilities of foam solutions are far superior to those of plain water. Tests have shown that foam is twice as effective as water in delaying ignition of materials. This property has been used extensively to hinder the progress of forest fire in Texas and California and to provide property protection in many fires. The knockdown time has been rated as three to five times faster for Class A foam solutions to plain water and the ability of the foam to affect three sides of the fire tetrahedron (oxygen, fuel, and heat. Far exceed the capabilities of water alone. It has been found that existing residential and commercial sprinkler systems can be easily converted to foam systems often for a fraction of the cost of a whole new system. Foam decreases the water damage that can be caused by a triggered sprinkler system to structures and their contents due to this low water content. A system like this is ideal to incorporate in buildings that contain precious or irreplaceable items such as found in museums, homes, and production or manufacturing plants.

There are many attributes to foam solutions. Its low mass and high volume let it stick to vertical and inclined surfaces, coat fuels and stays in place after application instead of beading and rolling off as water does. This sticking effect is due to the reduced surface tension in the water due to the bubbles and chemistry of the concentrate.

Gasses

FE-13, the newest of the clean agents to emerge from NFPA 2001, is one of the safest clean agents now available. FE-13, DuPonfs entry into the field, is U.L. listed and systems are currently available from Fireline and Kidde-Fenwal.

FE-13 (triflouromethane) is the safest of the three most commonly used clean agents (FE-13, FM-200 and Inergen). Systems are typically designed at 16-21% concentrations but FE-13 has no exposure restrictions until concentrations reach 30% or higher. This allows for customization of systems where the concentration can be set for specific applications.

Two other characteristics make this a unique agent that should be seriously considered for your clean agent requirements. First, nozzles can be located at heights of up to 25 feet as compared to only 12 feet for FM-200 systems. Second, due to its low boiling point, FE-13 can be used in temperatures as low as 40 degrees F.

As with other clean agents, FE-13 can be used in any area with high valued electronics such as computer facilities, battery rooms and telecommunications facilities. It also has many industrial applications including unheated storage areas.
The local Fire Department is the second line of defense against a fire. The Worcester Fire Department is less than one minute away from the Worcester Armory and is hooked

directly into the alarm system. The Fire Department should have a plan of the building that shows all pertinent information. This would include a complete floor plan, structural analysis, and a description of where people are likely to be present or exiting in the case of an emergency.

Laws and Legislation Regarding Historic Buildings

The laws and legislation governing the historic buildings in our country are spelled out in one piece of legislation, the National Preservation Act (NHPA). It is this act that makes it possible for historic properties to be displayed with their original looks and appearance. The NHPA also provides for government agencies to look after these properties as well as a national historic museum. Also, the state and local laws have been changed to allow for the preservation of historic buildings. The following is a basis for how the national, state, and local areas come together and allow for a specific plan to preserve historic properties under this Act.

National

The National Historic Preservation Act (NHPA) is the main piece of legislation which historic properties follow as their backbone and which preserves the historic values of the nation. The NHPA, which was enacted in 1966, was created due to concerns of historic resources not receiving the attention they deserved, were being altered, or lost because of public works projects the government thought necessary. In the 60's, laws only applied to a handful of nationally significant properties, and Congress realized a need for more protection of historic properties that were being harmed by government actions. It was nevertheless necessary and appropriate for the federal government to accelerate its historic preservation programs and activities. Overall, the NHPA lays the groundwork for the National Register, State Historic Preservation Programs, Section 106, and other sections which deal with the councils, committees and funds not relevant to this paper.

The National Register, or the National Register of Historic Places, is the official list of the nation's important and irreplaceable historic properties. It is part of a national program to recognize efforts to identify, evaluate, and protect our historic and archaeological resources. The register includes buildings, districts, sites, structures, and objects that retain their integrity and reflect some significant aspect of local, state, or national history and is maintained by the Secretary of the Interior. Listing on the register provides honor and distinction for significant properties and provides a basis for making informed planning and development decisions.

Under the NHPA, State Historic Preservation Programs were created which provided a State Historic Preservation Officer (SHPO), an adequate and qualified State historic preservation review board, and provided for adequate public participation. The responsibilities of each party are outlined in the NHPA and the duties of the SHPO are outlined as follows:

SHPO:

1. Direct and conduct statewide surveys of historic properties and maintain inventories of those properties.
2. Identify and nominate eligible properties to the National Register.
3. Prepare and implement a comprehensive statewide historic preservation plan.
4. Administer the State program of Federal assistance.

5. Advise and assist in carrying out historic preservation.

6. Ensure that historic properties are taken into consideration at all levels of planning and development.

7. Provide public information, education and training, and technical assistance in historic preservation.

8. Assist in local preservation programs.

9. Consult with the appropriate Federal agencies.

10. Advise and assist in the evaluation of proposals for rehabilitation projects that may qualify for federal assistance.

Section 106 of the NHPA requires federal agencies to consider how each undertaking can affect historic properties. An undertaking can be a varying amount of government activities: construction, rehabilitation and repair project, demolition, licenses, permits, loans, loan guarantees, grants, Federal property transfers. When one of these affects a historic property, the sponsoring agency is obligated to seek Council comments. Section 106 is as follows:

Section 106(16U.S.C 470f)

Advisory Council on Historic Preservation, comment on Federal undertakings.

The head of any Federal agency having direct or indirect jurisdiction over a proposed Federal or federally assisted undertaking in any State and the head of any Federal department shall, prior to the approval of the expenditure of any Federal funds on the undertaking prior to the issuance of any license, as the case

> may be, take into account the effect of the undertaking on any district, site, building, structure, or object that is included in or eligible for inclusion in the National Register. The head of any such Federal agency shall afford the Advisory Council on Historic Preservation established under Title II of this act a reasonable opportunity to comment with regard to such undertaking.

Section 106 review refers to the federal review process, which ensures that historic properties are considered during project planning, and execution. The Advisory Council on Historic Preservation administers the review process, which is an independent Federal agency. An agency must allow this council a reasonable opportunity to comment on the agency project.

Section 106 review has five basic steps:

1. Identify and evaluate historic properties - the agency begins by identifying the historic properties involved and then contacts the SHPO to gain background information.

   If properties that may be eligible but have not been included, the agency evaluates them against criteria published by the National Park Service, which maintains the register.

   If a property has already been included further evaluation is not ordinarily necessary.

2. Assess effects - the agency will then assess what effect the undertaking will have on the property. It will either have no effect, no adverse effect, or an adverse effect.

3. Consultation - if an adverse effect will occur. The agency consults the SPHO to find ways to make the undertaking less harmful. Consultations are meant to result in a Memorandum of Agreement (MOA), which outlines ways to make the necessary changes less harmful, or avoided.
4. Council comment - the council may comment, in which case, the MOA may be changed or have written comments attached.
5. Proceed - if executed, the agency proceeds under conditions of the MOA.

The Section 106 regulations also state that a state review system can be used instead of the standard Section 106-review process.

State

In the Massachusetts State Building Code, there is a special section, SECTION 635.0 HISTORIC BUILDINGS, which deals with Historic Buildings. Under this section, any building listed on the National Register of Historic Places is covered in this section. The section provides for the exception of certain building codes that would normally be enforced, and deals mainly with the fire systems and means of egress from a building. Every attempt is usually made to comply with standard building and fire codes. When these cannot be met without significantly impairing a structure's integrity and character, the management and use of the structure, rather than the structure itself, will be modified to minimize potential hazards.

In the state of Massachusetts, recommendations for listing on the National Register are generally made to the staff of the Massachusetts Historical Commission (MHC) by the local historical commission on the basis of a local survey of historical assets. Nominations are then reviewed by the MHC and forwarded to the Keeper of the National Register for approval. When new projects are initiated, the MHC has a form that must be completed. The form asks specific questions relative to the impact being made by this project with respect to the building and the surroundings. This form can be found as appendix A2. The MHC consists of twelve commissioners, appointed from various disciplines by the Secretary of State, to review state and federal preservation programs. Massachusetts has approximately 1,500 sites, districts, buildings, and objects listed on the National Register representing a total of approximately 32,000 properties. The SHPO for the State of Massachusetts is Valerie A. Talmage.

Planning and zoning laws in Massachusetts have also been changed to accommodate historic buildings. In Lyman v Planning Board of Winchester, the ruling was that the town could waive strict compliance with its laws and legislation when unreasonable or unusual.

Local

Worcester Polytechnic Institute has drafted its own preservation plan. The plan, completed in May 1997, provides a plan for which the historic look, feel, and culture of the WPI campus will be preserved even through reconstruction and expansion of existing buildings. The preservation plan was undertaken pursuant to a MOA, which was signed by the MHC, Massachusetts Health and Educational Facilities Authority and WPI. This plan included the following:

1. An inventory of historic buildings.
2. Identification of those structures listed or eligible for listing in the National Register of Historic Places.
3. An assessment of current conditions
4. Recommendations for maintenance and rehabilitation.
5. An evaluation of impacts of current or proposed construction projects on historic resources.

Concluding this section, the laws and legislation that govern historic buildings are here to protect our national heritage. The plan used as an example is one that can be clearly seen to work. It is from this plan that can be shown a specifically developed plan should be written for the Worcester Armory project and implemented to include all renovations, and alterations being currently considered. This plan should consider a way to keep the historic feel but increase the current useful capacity of the Armory.

Evaluation of Worcester Armory

Introduction

At first glance of the armory it easy to tell that the building has been around for a number of years, through those years it has undergone a few renovations but none of which included the implementation of a early warning or fire suppression system in the building. This presents a interesting dilemma for our group, how do we install these systems and still retain the historical integrity of the building but allow for maximum protection of the artifacts and people inside.

Pre-Existing Fire Safety Measures

The armory as it now stands has very little in the way of protection against fire; the measures in place are far from adequate for a building with that much information in it. The building has anti theft security system in place that alerts police of a break in, this is important because we can do the wiring for our system in much the same way. The boiler is also equipped with a detection system for the pilot light; if the pilot light goes out the fire department is notified and arrives in between 4 to 6 minutes. One severe problem that is prevalent through out the armory as a whole is the wiring of electricity. There is far from the necessary amount of outlets in any room in the armory. By not having the right amount outlets people overload one outlet and by doing this cause an electrical fire. Along with the lack of outlets there are exposed wires in various places throughout the armory (especially on the third floor). There are no smoke detectors of any kind throughout the building as a hole, this is a obvious problem because there is absolutely no early warning detection of the fire in which case if a fire begins it can burn much longer without detection causing far greater damage and harm to the people inside.

Along with the lack of smoke detectors the amount of extinguishers is far from adequate. There is only one on every floor located in the main hallway of the floor. The law states that there must be one extinguisher every 75 ft in any direction the armory falls short of meeting that ordinance. Along with the lack of fire extinguishers there is the absence of a sprinkler and ventilation system to suppress a fire if it were to begin. The last of the existing fire safety measures is the fire escape, which is far from useable. The base of the fire escape has been hit by a car and one of the load bearing beams has been bent. For the third and second floor this fire escape is the only other escape route other than the main stairs.

From this overall evaluation it is easy to see that there is a lot to work with in this armory. An implementation of an early warning detection system along with a fire suppression system is necessary.

Floor by Floor Evaluation
Basement

I. Problems

The consists of a long corridor with rooms branching of the corridor, most of these rooms are supply rooms and house old documents and banners that have not been integrated into the exhibits. Along with supply rooms there is also a locker room and old rifle range along with the boiler room. As I stated earlier the boiler possesses an early warning detection system for the pilot light. The rifle room now stores stacks upon stacks of documents and old artifacts such as flash lights from WWII, the same goes for many of storage rooms. Except for the locker room, which hardly gets used anywise, the basement remains relatively empty except for the stuff in storage. Yet another problem in the basement is the use of radiators on the ceiling which could present a problem with the installation of sprinklers. At first glance the basement seems very unorganized and a nightmare if a small fire were to begin. The fire could burn undetected for at least ten to fifteen minutes by then it could be burning out of control. The building would burn undetected if no one were in the building because people are the only form early warning in this building.

II. Solutions

The first solution to the problem with the basement is organization; the placement of documents into filing cabinets would help prevent the spread of fire throughout the basement. Yet another easy fix is putting doors with door closers on every room entrance by doing this you help to localize the fire and to slow down its progress through the building. By following through with those two suggestions you would not hurt the authenticity of the building but you just help the fire protection of the floor a great deal by helping the fire to stay local. This in addition to a detection and suppression system suggested later makes the floor 100% better.

First Floor

I. Problems

The first floor mainly consists of war exhibits; there is no real storage of documents on this floor. Once again on this floor there are inadequate amount extinguishers on the floor and the complete absence of smoke detectors and sprinklers. Although one positive to this floor is that every room has to exits to the main hallway and every exit has a door to prevent the rapid expansion of the fire throughout the first floor. One major problem on this floor is the lack of outlets, since there are a few offices on this floor a few outlets get overloaded which presents a major problem. There is also a gymnasium on this floor towards the back of the building. This is used as drilling and training room; there is not much in it besides banners. The gym does not pose much of a problem because it is an addition so it can be easily updated. The reaction time for a fire on this floor is probably around 5 minutes because this is the only floor were there is usually someone present. The first floor is in the best shape from a fire protection standpoint of any of the four floors.

II. Solution

The one obvious solution is to do a little rewiring and adding a few more outlets, thus reducing the chance of an electrical fire. In addition to rewiring smoke detectors and a fire suppression system needs to be added and incorporated into the buildings structure.

Second Floor

I. Problems

The problems that arise on the second floor are basically the same as the ones that came about on the first floor. The major problem is exposed wiring, and lack of any fire detection or suppression on the floor. This floor is home to most of the artifacts of the armory, most of the artifacts are placed on display in glass cases therefore they are protected from water damage from sprinklers if sprinklers are implemented. Although every room on this floor has to exits the only way to get off this floor is to go down main stairwell. Another problem on this floor is that all the doors between the rooms are propped open with all the doors being left open the fire will travel much faster through the floor. The walls on this floor are rather thin and probably would go up relatively quick. The approximate time before you realize there is a fire on this floor is around 5-10 minutes depending on the time off day. From 10:00am to 3:30pm tours are given of the armory so usually people are poking around upstairs and would find a fire rather quickly. Anytime other than the ones specified there is a chance that discovery of the fire could take much later thus making for a much more dangerous situation.

II.Solutions

The problems on the second floor are relatively easily to fix except for two. The doors on the floor can installed with automatic closers that would help greatly in stoppage of rapid progression of the fire throughout the floor. The first major repair for the floor is the renovation of the fire escape, the repairing of the escape would allow for two exits on every floor (2^{nd},3^{rd},4^{th}), this repair would be a little pricey but in our opinion is a necessary one. The second is the instillation of detectors and a suppression system, which are also sorely needed.

Third Floor

I. Problems

The third floor is almost exactly the same as the second in the set up of the rooms. The second floor has the same problem with the wiring as the first floor does in the offices, especially in the study on the front right corner of the building. This corner of the building is a library of sorts. The major problem of library is that there is only one outlet on the floor and it is located in this room. Along with the same problems as the first floor and second floor, the second floor one more problems. The major problem on the third floor is in the archive room. As in the basement supply rooms the third floor archive rooms are used for storage of documents dating all the way back to the American Revolution and other such paper work dating all the way up to the 20^{th} century. All of this paper work is in boxes on shelves or in boxes on the floor. This floor is very unorganized like the basement supply rooms. This floor also has the same problem with only one useable escape which is the main stairwell.

II. Solutions

The suggestions for this floor are just the same as for previous floors. Fix the fire escape and rewire some of the rooms to relieve the pressure on the one outlet on the floor. A new suggestion for this floor is a fire proof vault for the room, which contains the very important older documents. This along with other suggestion from other floors would help in the renovation of the third floor.

Fourth Floor

I. Problems

The problems on this floor are clearly visible everything is exposed down to the studs on this floor. That means this floor would be the easiest to renovate because there is not authenticity to maintain on the floor. On this floor the fire escape is most important because it three flights down stairs to escape the building in case of emergency. But the suggestion to knock down the walls and have a large open space would be a big mistake(see appendix A. 1). If this floor is to be used renovations must be down to each room.

II. Solutions

The solution for this floor is easy, redo every room and bring it all the way up to code. Which means make every wall and ceiling fire rated. Smoke detectors and sprinklers in every room. In addition to those improvements completely rewire the whole floor and fix the fire escape.

Conclusion

After a floor by floor analysis of the armory it was two things were obvious, first that there was absolutely no pre-existing fire safety measures in the whole building except for 4 extinguishers in the building. Although some of the suggestions were easy such as automatic door closers, and putting the documents into filing cabinets. The major recommendation that this IQP group will make for the armory is the installation of detectors and a suppression system. A second recommendation for the armory is the installation of a HVAC system because there is already a pre-existing central vent that runs through the center of the building. Installation of the HVAC system will help greatly in the ventilation of smoke and toxic gases from a fire.

For a sprinkler system our group recommend s a dry pipe sprinkler system for one main reason, the heat in the building gets turned off during the winter and a dry pipe system allows for the prevention of the pipe freezing. As far as the fire detection system we chose a combination VESDA (Very Early Smoke Detection Apparatus), this system covers 2000 m^2 and has a response time of 1 minute for a relatively small fire of 10-100 watts. Along light beam detectors rooms with high ceilings such as in the drilling hall. We suggest these detects because the sensing of heat in these rooms take much longer to detect because of the high ceilings. For the rare artifacts such as the ones on the third floor and in the basement we suggest putting the artifacts in room size fireproof vaults. By putting the items in those vaults you are securing that nothing will every happen to the artifacts.

Fourth Floor Office Plan

The use of the 4rth floor in the armory is strongly recommended to not be used as office space until that floor can be updated in fire safety codes. However, to be able to have the offices on the floor the armory officials must repair wiring, cut down on combustible items, and have a fire safety plan for the floor. The armory does not have any plans for improvement of these items.

On the fourth floor there is only one route in and one out. So if there is a fire there is only one means of escape and if the stairwell is on fire then the occupants would be trapped on the floor and be grave danger. There is a fire escape on the floor, however the escape stairs are not structurally sound and should be condemned. For one, the staircase itself is not bolted securely and the bolts that are in the building are corroded and could not possibly be able to support the load of people on them. Also, the support beams are extremely bent at the base of the staircase. These things make the staircase almost as dangerous as a fire in the building.

There is also no form of fire prevention in the armory what so ever. Whether it is sprinklers or extinguishers there is nothing to prevent any small fires from becoming larger blazes. The existing walls and wall coverings are not fire rated material and could not stop any flames from spreading on the floor. As for early warning system, there is nothing to detect and then alarm occupants that there is a fire on the floor or anywhere in the building.

The addition of office materials also provides more fuel for fire. Where there is a desk there is a stack of papers and computers and also nearby there is a waste container with garbage that is combustible fuel for a fire. From the computers there is the use of the electrical systems, which are outdated by many years, thus being a severe fire hazard. Adhesives and correcting fluids are also a few of the many office materials that are highly flammable and are used often in an office. With the many workers on that floor, a no smoking policy must be implemented. Cigarettes have been known to be the cause of many fires. The installation of offices this also brings decorations into play for fire fuel. The holidays brings many decorations to a office during Christmas lights and trees fill up the office which can burn very easily when flames are near.

APPENDIX A

MASSACHUSETTS HISTORICAL COMMISSION
~~60 Boylston Street, Room 310~~ 220 Morrissey Boulevard
Boston, MA ~~02116~~ 02125

PROJECT NOTIFICATION FORM

Project Name____

Location/Address____

City/Town____

Project Proponent

Name____

Address____

City/Town/Zip/Telephone___________________________________

Agency license or funding for the project (list all licenses, permits, approvals, grants or other entitlements being sought from state and federal agencies).

Agency Name Type of License or Funding (specify)

Projecre Description (narrative)

Does the project include demolition? If so, specify nature of demolition and describe the building('s) which are proposed for demolition.

Does the project include rehabilitation of any existing building? If so, speaify nature of rehabilitation and describe the building(s) vhich are proposed for rehabilitation.

APPENDIX A (continued)

Does the project include new construction? If so, describe (attach plans and elevations if necessary).

To the best of your knowledge, are any historic or archaeological properties known to exist within the project's area of potential impact? If so, specify.

What is the total acreage of the project area?

Woodland_________acres	productive Resources:
Wetland _________acres	Agriculture________acres
Floodplain __ , acres	-Forestry________acres
Open Space_________acres	Mining/Extraction_______acres
Developed_________acres	Total Project Acreage_______acres

What is the acreage of the proposed new construction?________acres

What is the present land use of the project area?

What has been the previous land use of the project area?

Please attach a copy of the section of the USGS quadrangle map which clearly Harks the project location.

This Project Notification Form has b«an submitted to the KHC in compliance with 950 CMR 71.00.

____________________________________ ________________
Signature of Person submitting this form Date

Name______________________________

Address______________________________

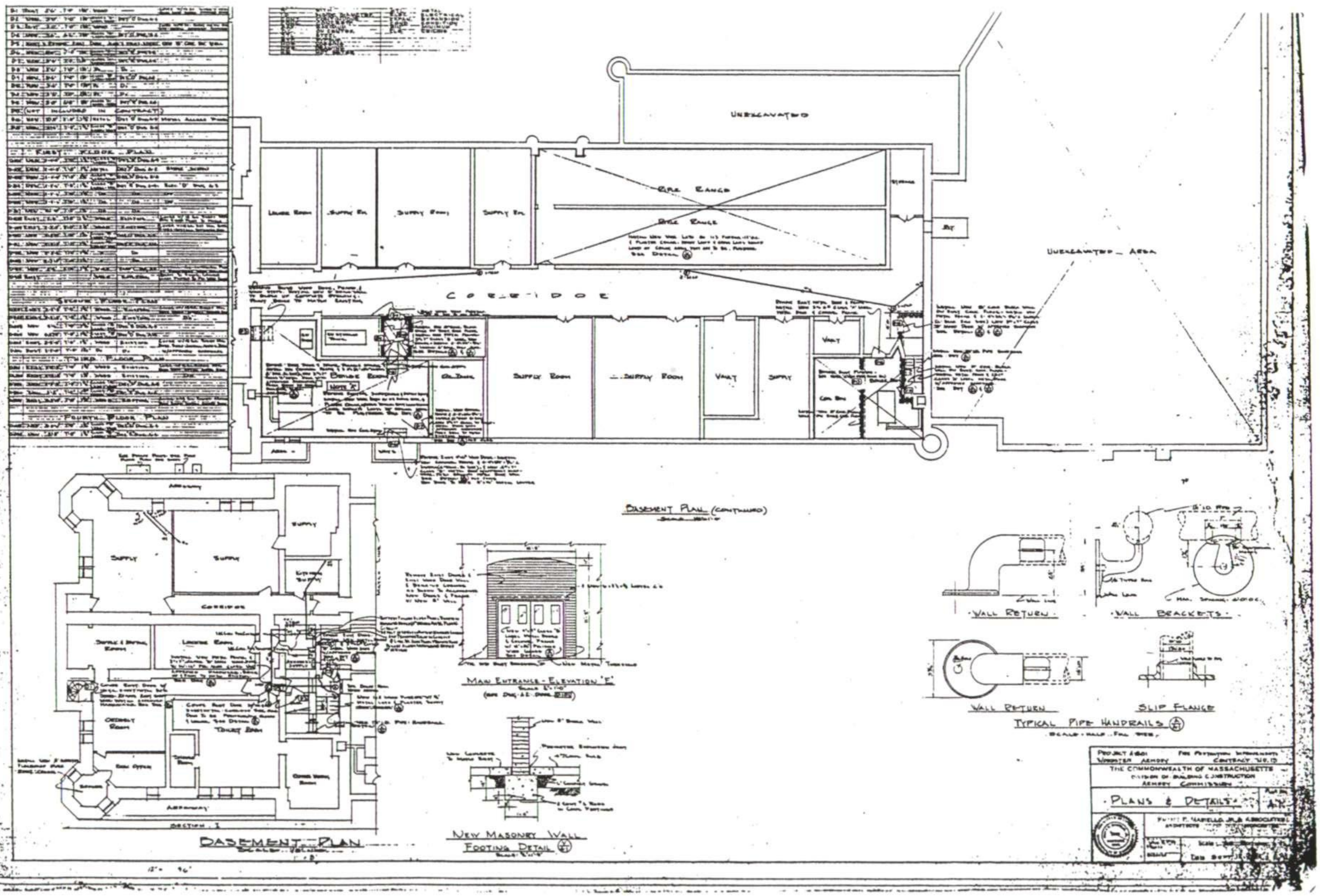
____

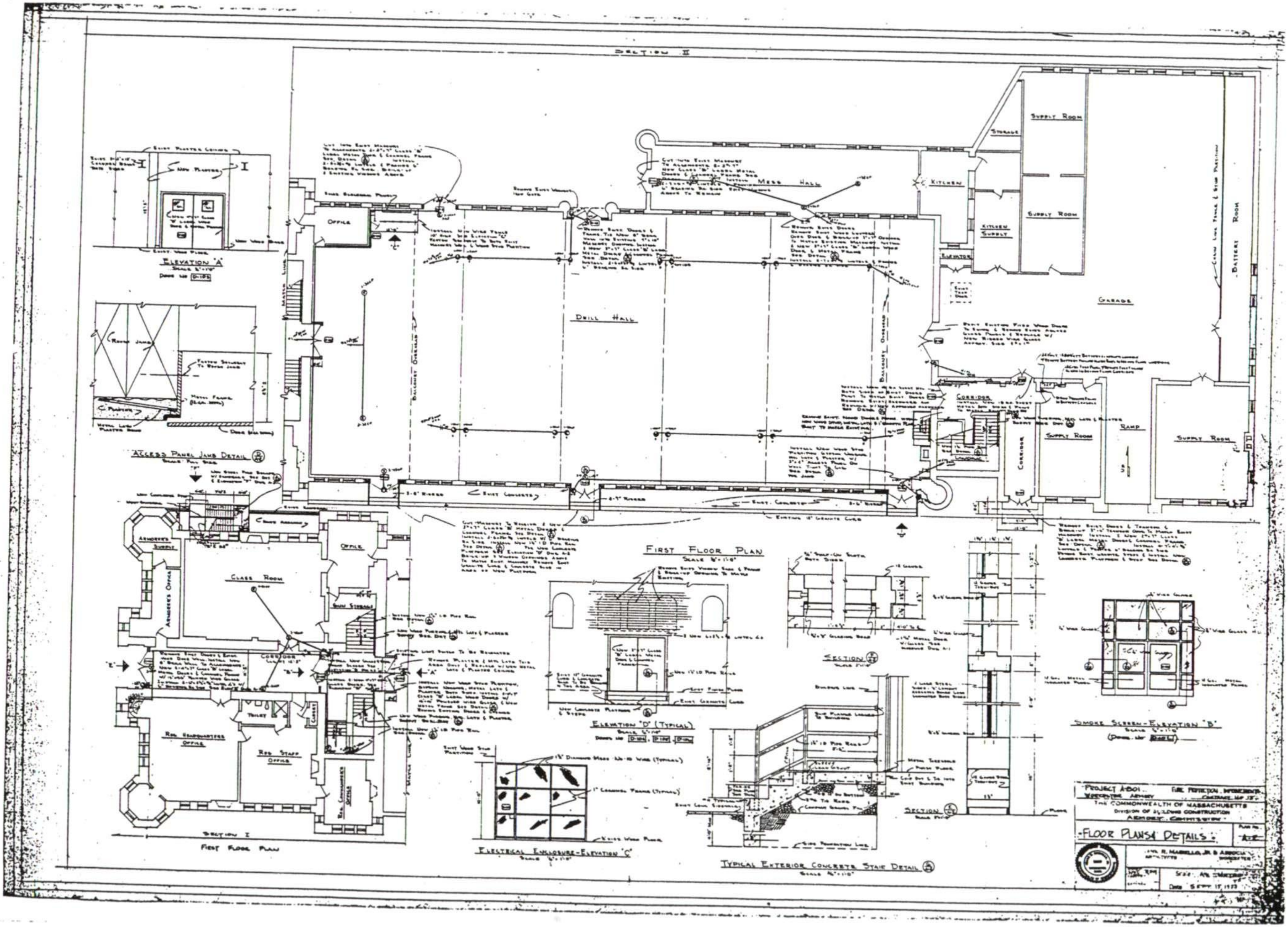
City/Town/Zip_________________________

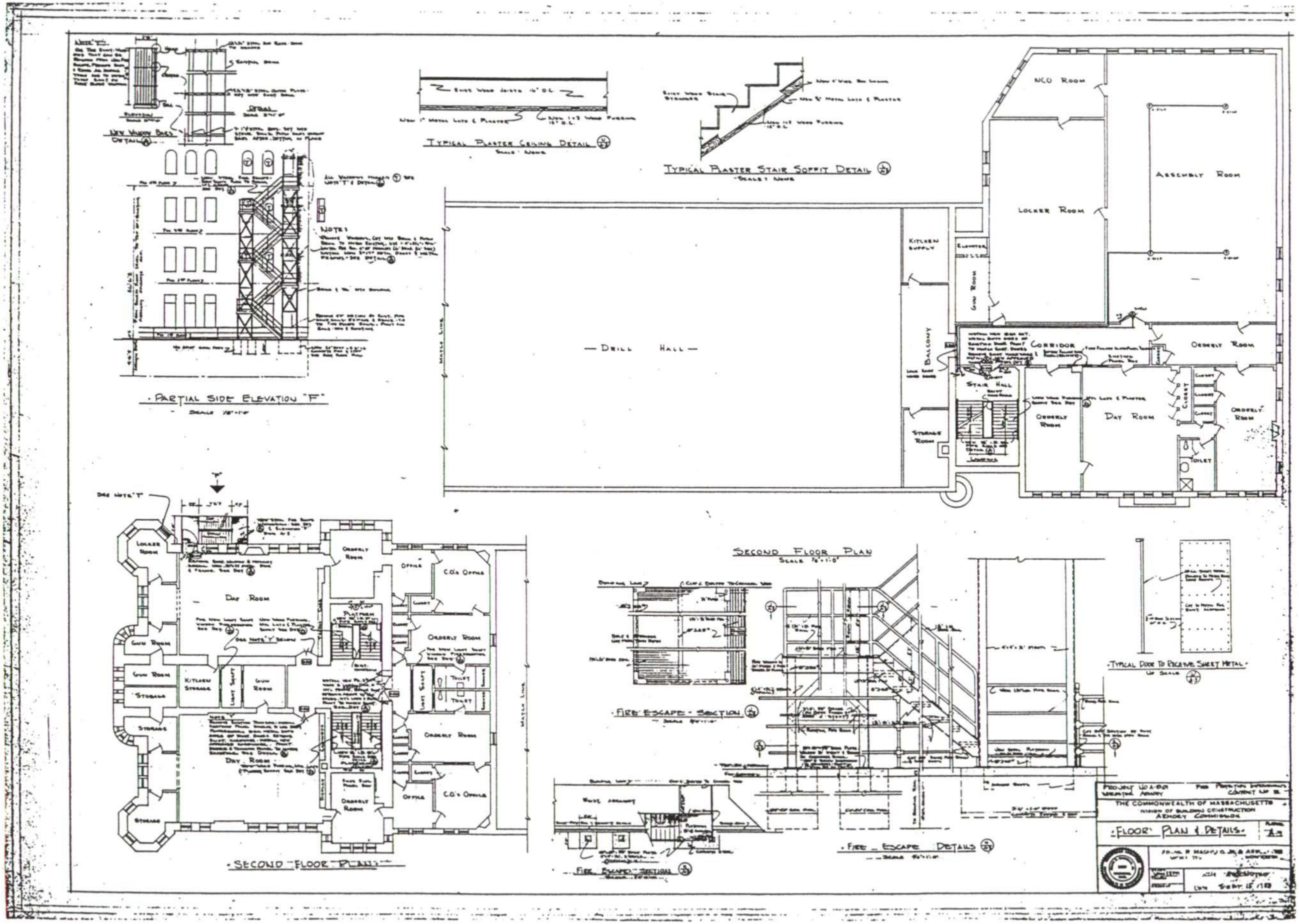
Telephone___________________________

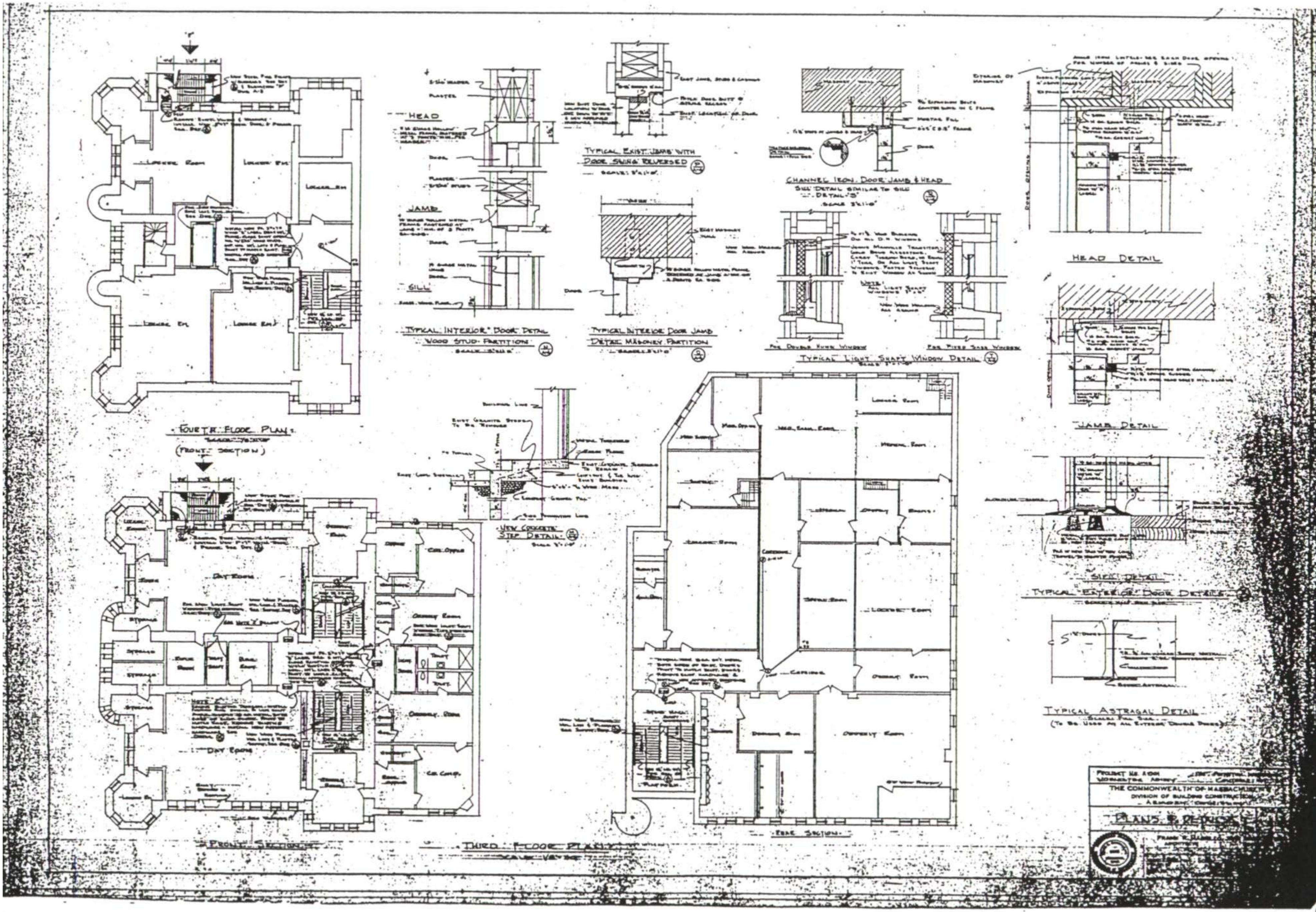
REGULATORY AUTHORITY

950 CMR 71.00: M.C.L. c. 9, ss. 26-Z7C as amended by Si. 1988. c. 254.


UNEXCAVATED
RIFLE RANGE
CORRIDOR
LOCKER ROOM
SUPPLY RM.
SUPPLY ROOM
VAULT
SUPPLY
UNEXCAVATED AREA
BASEMENT PLAN (CONTINUED)
ARMORY
CORRIDOR
TOILET ROOM
BASEMENT PLAN
MAIN ENTRANCE - ELEVATION 'E'
NEW MASONRY WALL
FOOTING DETAIL
WALL RETURN
WALL BRACKETS
SLIP FLANGE
TYPICAL PIPE HANDRAILS
THE COMMONWEALTH OF MASSACHUSETTS
ARMORY COMMISSION
PLANS & DETAILS


SECTION II
SUPPLY ROOM
STORAGE
SUPPLY ROOM
KITCHEN
KITCHEN SUPPLY
ELEVATOR
MESS HALL
OFFICE
DRILL HALL
BALCONY OVERHEAD
GARAGE
BATTERY ROOM
CORRIDOR
SUPPLY ROOM
RAMP
SUPPLY ROOM
ELEVATION "A"
ACCESS PANEL JAMB DETAIL
FIRST FLOOR PLAN
ARMORER'S SUPPLY
ARMORER'S OFFICE
CLASS ROOM
OFFICE
CORRIDOR
TOILET
REG. HEADQUARTERS OFFICE
REG. STAFF OFFICE
REG. COMMANDER'S OFFICE
SECTION I
FIRST FLOOR PLAN
ELEVATION "D" (TYPICAL)
SECTION
ELECTRICAL ENCLOSURE-ELEVATION "C"
TYPICAL EXTERIOR CONCRETE STAIR DETAIL
SMOKE SCREEN-ELEVATION "B"
PROJECT A-801
FIRE PROTECTION IMPROVEMENTS
THE COMMONWEALTH OF MASSACHUSETTS
DIVISION OF BUILDING CONSTRUCTION
FLOOR PLANS & DETAILS
DATE SEPT 17, 1973


NCO Room
Assembly Room
Locker Room
Kitchen Supply
Elevator
Gun Room
Balcony
Storage Room
Drill Hall
Match Line
Corridor
Orderly Room
Stair Hall
Day Room
Closet
Toilet
Typical Plaster Ceiling Detail
Typical Plaster Stair Soffit Detail
Partial Side Elevation "F"
Notes
Second Floor Plan
Locker Room
Gun Room
Kitchen Storage
Light Shaft
Storage
Office
C.O.'s Office
Platform
Fire Escape - Section
Fire Escape Details
Typical Door to Receive Sheet Metal
Project U04-801 Wrentham Armory
Fire Protection Improvements
The Commonwealth of Massachusetts
Division of Building Construction
Armory Commission
Floor Plan & Details
A-3



HEAD
JAMB
SILL
TYPICAL INTERIOR DOOR DETAIL
WOOD STUD PARTITION
TYPICAL EXIST. JAMB WITH
DOOR SWING REVERSED
TYPICAL INTERIOR DOOR JAMB
DETAIL MASONRY PARTITION
CHANNEL IRON DOOR JAMB & HEAD
SILL DETAIL SIMILAR TO SILL
DETAIL "B"
TYPICAL LIGHT SHAFT WINDOW DETAIL
HEAD DETAIL
JAMB DETAIL
SILL DETAIL
TYPICAL EXTERIOR DOOR DETAIL
TYPICAL ASTRAGAL DETAIL
(TO BE USED AT ALL EXTERIOR DOUBLE DOORS)
FOURTH FLOOR PLAN
(FRONT SECTION)
NEW CONCRETE
STEP DETAIL
DAY ROOM
THIRD FLOOR PLAN
FRONT SECTION
REAR SECTION
THE COMMONWEALTH OF MASSACHUSETTS
DIVISION OF BUILDING CONSTRUCTION
PLANS & DETAILS

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