FIRE PROTECTION
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Commissioning: A New Buzzword?

Commissioning: A Federal Agency Perspective

Unsatisfactory Sprinkler Performance

Marriott's Inspection Program

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From the TECHNICAL DIRECTOR

Salaries Earned by Fire Protection Engineers

During early 2010, the Society of Fire Protection Engineers conducted a survey of fire protection engineers to develop a snapshot of employment compensation as a function of work experience and other factors. This is the 15th time that SFPE has conducted this survey since 1976. The last survey, conducted in 2007, evaluated compensation received in 2006. The 2010 survey asked for information regarding compensation in 2009. Overall, the median salary for fire protection engineers was $US 110,500, which was 12.5% higher than was found in the 2007 survey.

A total of 658 people participated in the survey, which was administered using a web-based tool in early 2010. The survey contained questions about experience, job responsibilities, age, base compensation, incentive pay and other benefits.

The vast majority (87%) of respondents were from the United States, so the results are primarily illustrative for fire protection engineers who work in that country. Most respondents (90%) were members of the Society of Fire Protection Engineers.

The survey found annual average growth of 4.2% in total compensation (base pay plus incentive pay) over each of the last three years, which is down from the annual increase of approximately 6% found in 2007. This can be contrasted with the U.S. national average salary increase of 3.9% in 2008 and 2.2% in 2009.

While this shows that fire protection engineering has weathered the economic downturn well, not all of the findings have been positive. There has been a large increase in the number of unemployed fire protection engineers; 7.2% of respondents indicated that they were unemployed at some point during 2009, which is an increase from the 0.2% who were unemployed during 2007. However, this unemployment rate is below the U.S.-national rate of approximately 10% in 2009.

Another factor that could have impacted the increase in salaries was that a higher number of people with professional engineer's licenses responded to the 2010 survey than responded to the 2007 survey. People with professional engineer's licenses constituted 44% of the respondents to the 2007 survey and 65% of the respondents to the 2010 survey. The survey found that having a professional engineer's license (P.E. or P.Eng.) corresponds to a 10% higher median salary when compared to people who do not have a professional engineer's license.

Median base salaries increased steadily from $70,000 for fire protection engineers with less than six years experience to $120,000 for fire protection engineers with 26 to 30 years of experience. However, median salaries did not continue to increase with experience beyond 30 years.

Salaries showed an appreciable gain as a function of experience for fire protection engineers who were new to the profession. Those with two years of experience had a median base salary of $63,000, which increased to $70,000 for those with three years of experience, $74,500 for those with four years of experience, and $75,000 with five years of experience. Collectively, this is an increase of almost 20% over three years.

For the first time, the 2010 salary survey explored the correlation between professional responsibility and salary. As would be expected, there was a direct correlation between responsibility and base salary. Engineers who have the least amount of responsibility and work under the close supervision of senior engineers had a median salary of $55,000, and engineers with the most responsibility earned a median base salary of $138,000.

In addition to base salary, 70% of respondents reported that they also received incentive-based pay, with a median value of almost $10,000. Incentive-based pay included bonuses, overtime pay, commissions, etc. Twenty percent of entry-level engineers reported that they received incentive-based pay, and the fraction of engineers who received incentive-based pay increased to approximately 70% for more experienced engineers. For all but the most experienced engineers, the incentive-based pay was 8-9% of base salary; the most experienced engineers received incentive-based pay that totaled 16-18% of their base salaries.

Education had an impact on the total salary received by fire protection engineers. Fire protection engineers who had 10 or fewer years of experience received 15%-22% more in total compensation if they had a master's degree compared to those with similar experience who only had a bachelor's degree. This difference diminished for fire protection engineers with 11 or more years of experience.

Supervisory responsibility affected the total compensation received. Fire protection engineers with 11 or more years of experience received on average 12% more in total compensation if they had supervisory responsibility than that received by fire protection engineers who did not. However, there was almost no difference in the total compensation received by fire protection engineers with 10 or fewer years of experience who had supervisory responsibility when compared to those without supervisory responsibility.

While most of the respondents were from the United States, there were some interesting findings regarding fire protection engineers who worked outside the United States. The median salary for fire protection engineers who worked in Canada was $C 96,500, and the median salary in Sweden was € 45,000. The median salary increase in 2009 was 3% in the United States and Canada, compared with 0% in New Zealand and Australia. The median salary increase was much higher in the Middle East, at 7% in Saudi Arabia and 9% in the United Arab Emirates. However, as the sample sizes were very small, conclusions for countries other than the United States should be made with caution.

The full report can be viewed at *www.sfpe.org*.

Morgan J. Hurley, P.E., FSFPE
Technical Director
Society of Fire Protection Engineers

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By Frederick W. Mowrer, Ph.D., P.E., FSFPE

In common usage, the term "preventive maintenance" is associated with a systematic process of inspection and servicing of equipment and facilities for the purpose of keeping them in satisfactory operating condition and avoiding major failures. A simple example of this is the planned maintenance most people perform on their personal automobiles at regular intervals. In industrial settings, such as commercial power plants, a wide range of preventive maintenance activities are frequently scheduled so that they can be carried out during planned system outages or shutdowns in order to avoid additional unscheduled loss of production time.

When applied to fire safety in the built environment, the term "preventive maintenance" has at least two connotations. On one hand, preventive maintenance is an important aspect of keeping buildings, equipment and processes operating properly to reduce the likelihood of a fire occurring due to a system malfunction. On the other hand, preventive maintenance is also an important aspect of keeping fire safety systems in proper operating condition in case a fire does occur. Because fire safety systems are expected to sit idle for years or even decades and then respond on demand under fire conditions, these systems should be subjected to rigorous inspection, testing and maintenance (ITM) procedures on a regular schedule to help assure that they will perform as expected when needed.

The two current model fire codes in the United States, the *International Fire Code (IFC)* published by the International Code Council (ICC) and the *Fire Code (NFPA 1)* published by the National Fire Protection Association (NFPA), include chapters that address hazards associated with common building services and systems, such as electrical, HVAC, elevators, fuel-fired appliances, emergency and standby power systems, and commercial kitchens. Since 2000, the ICC has also published the *International Property Maintenance Code (IPMC)* in recognition of the need for a modern, up-to-date code for regulating the maintenance of existing buildings. These fire and property maintenance codes generally require building services to be designed and installed in accordance with recognized standards and maintained to provide the levels of service and performance contemplated in their designs.

Similarly, the *IFC*, *NFPA 1* and the *IPMC* include chapters that address the maintenance of fire protection systems and features, including means of egress and required fire resistance ratings. For example, in the chapter on fire protection systems in the *IFC*, there is a requirement that "fire detection, alarm and extinguishing systems shall be maintained in an operative condition at all times, and shall be replaced or repaired where defective." This requirement extends to fire protection systems and equipment that are not mandated by regulation, which must either be properly inspected, tested and maintained or removed from the building. The *IFC* identifies reference standards for the maintenance of different types of fire protection systems, including *NFPA 25* for water-based fire suppression systems and *NFPA 72* for fire alarm systems.

Over the past two decades, standards for the ITM of fire protection systems have become more rigorous as well as more comprehensive. For example, the first edition of the *NFPA 25* standard was published in 1992 to replace the recommended practices contained in the *NFPA 13A* guide with mandatory requirements that are suitable for regulatory adoption and enforcement. As of the 2008 edition, *NFPA 25* now includes provisions that address the need to evaluate the adequacy of installed fire suppression systems when changes in use or hazard occur. Such changes in use or hazard are currently among the leading causes of automatic sprinkler system failures. From a risk management perspective, a process should be in place to monitor for changes in use or hazard that should trigger an engineering evaluation of the fire protection systems installed within a facility.

When large fires do occur, it is not unusual to find one or more lapses in the preventive maintenance measures that either were in place or should have been in place before the fire occurred. Such lapses may be associated with the cause of the fire, with the failure to control the fire, or with both factors. The fire record is replete with cases where lapses in preventive maintenance and risk management measures contributed to the likelihood or the magnitude of the fire loss.

The MGM Grand Hotel fire that occurred in Las Vegas in 1980 is a case in point. The MGM Grand Hotel was approved without sprinkler protection in the deli restaurant where the fire started on the basis that the deli would be open and occupied 24 hours a day. Within a few years, however, the hours of operation were reduced, but sprinkler protection was not extended to cover the deli. Apparently, nobody recognized that this change in operation should have triggered a reappraisal of the fire protection plan for the deli.[1]

Frederick W. Mowrer is with the California Polytechnic State University.

Reference:

1 Mowrer, F., Williamson, R., and Fisher, F., "Analysis of the Early Fire Development at the MGM Grand Hotel," *Proceedings of the Second International Conference on Fire Research and Engineering*, Society of Fire Protection Engineers, 1997.

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NFPA Issues Alerts on Antifreeze in Residential Sprinkler Systems

The National Fire Protection Association (NFPA) Standards Council has banned the use of antifreeze solution in residential fire sprinkler systems for new construction until further action by NFPA consensus standards committees, and NFPA has issued a follow-up to its July 2010 safety alert to provide updated guidance on the use of antifreeze in residential fire sprinkler systems.

The council action and updated alert followed new research that was conducted after a fire incident raised concerns about antifreeze solutions in residential fire sprinkler systems. According to James M. Shannon, president of NFPA, the key findings of the new research were as follows:

- Antifreeze solutions with concentrations of propylene glycol exceeding 40 percent and concentrations of glycerin exceeding 50 percent have the potential to ignite when discharged through automatic sprinklers.
- Both the 40 percent propylene glycol and 50 percent glycerin solutions demonstrated similar performance to that of water alone for fire control throughout the series of tests.
- Based on the results of this research, antifreeze solutions of propylene glycol exceeding 40 percent and glycerin exceeding 50 percent are not appropriate for use in residential fire sprinkler systems.
- Consideration should be given to reducing the acceptable concentrations of these antifreeze solutions by an appropriate safety factor.

For more information, including design guidance for new and existing systems, go to *www.nfpa.org/antifreeze.*

Study Analyzes Effects of Firefighting Crew Sizes

A landmark study coordinated by the National Institute of Standards and Technology (NIST) is the first to put numbers to the effect of changing the size of firefighting crews responding to residential fires. Performed by a broad coalition in the scientific, firefighting and public-safety communities, the study quantifies the effects of crew sizes and arrival times on the fire service's lifesaving and firefighting operations for residential fires. Until now, little scientific data have been available.

The research team found that four-person firefighting crews were able to complete 22 essential firefighting and rescue tasks in a typical residential structure 30 percent faster than two-person crews and 25 percent faster than three-person crews.

"The results from this rigorous scientific study on the most common and deadly fires in the country—those in single-family residences—provide quantitative data to fire chiefs and public officials responsible for determining safe staffing levels, station locations and appropriate funding for community and firefighter safety," says NIST's Jason Averill, one of the study's principal investigators.

For more information, go to *http://bit.ly/cC4c2k or www.nist.gov.*

COMMISSIONING: A NEW BUZZ WORD?

By David R. Hague, P.E.

Commissioning has been around for a long time, but it has been traditionally considered the testing and start-up of a system or component. Most project managers in the construction trade would consider commissioning to occur at the end of a project when the system(s) have been installed and are ready for testing and turnover to the building owner. That is the way things have been done for many years. Commissioning in other trades has basically meant the same thing. Ships are commissioned when completely built and ready for launch. The space station was commissioned when its main core was assembled and ready for occupancy. An HVAC system is commissioned after final testing and balancing are performed.

So how has commissioning changed? Well, that can be answered by the philosophy of commissioning as a womb-to-tomb process where commissioning begins in the planning phase of a project and continues during construction (including acceptance testing) and throughout the service life of a building or system. That's not to say that FPEs continually test and inspect an existing system or building as vigorously as during construction. But part of the philosophy of commissioning is to prepare the maintenance staff for the inspection, testing and ongoing maintenance needs of the system so the system will function as intended, with as few issues as possible, throughout its entire service life. This is a process that Liberty Mutual refers to as human element—keeping systems functioning at all times.

Every construction project can be divided into four basic components: pre-design (or planning), design, construction and occupancy. Commissioning must play a part in all of these phases. In the pre-design phase, the owner (who pays for all of this work) establishes the project requirements and determines whether commissioning is needed at all. During the design phase, commissioning may take the form of oversight of the design to provide a system of checks and balances to verify that the installation complies with the project specifications. During construction, commissioning may require periodic inspections of the installation, pre-functional testing and acceptance testing activities. And, during the occupancy phase, commissioning involves development and submission of turnover documentation (operation and maintenance manuals and as-built drawings and calculations), training of personnel and the establishment of an ongoing inspection, testing and maintenance program.

During construction, commissioning may require periodic inspections of the installation, pre-functional testing and acceptance testing activities.

PRE-DESIGN PHASE

The pre-design or planning phase should include a discussion with the owner's planning team to determine the complexity of the project, which will in turn drive the need for a formal commissioning program. The owner's planning team usually consists of the owner or owner's representative; the design team, consisting of the architect and other design professionals; the insurance representative; installing contractor; manufacturer's representatives; the authority having jurisdiction (AHJ) and, if needed, the commissioning team.

The planning team may also include a facility manager and third party testing representative. Together, in addition to the usual project planning tasks, this group should develop the owner's project requirements (OPR) for commissioning. The OPR will establish the requirements for all of the commissioning activities and should include the following items at a minimum:

1. Infrastructure requirements (roads, site access, utilities)
2. Facility type, size and height
3. Intended use
4. Occupancy classification, number of occupants, and hours of operation
5. Future expansion requirements
6. Applicable codes and standards
7. Specific user requirements
8. Training requirements
9. Warrantee and operation and maintenance requirements
10. Integrated system requirements
11. Specific performance criteria
12. Third party requirements

Producing this information in the initial stages of a project can help prevent any misunderstanding of the project requirements and can help avoid the possibility of costly re-work or change orders. For example, Liberty Mutual has "Interpretive Guides" to several NFPA standards and the firm's loss prevention engineers ensure that the design team is fully aware of these requirements when specifying a fire protection system for a policyholder's property. It is important to note that each project will have its own unique characteristics.

While the project team should be aware of the roles played by each entity on the team, for the commissioning agent the main focus will be project oversight, which generally includes:

- Establishment and execution of a commissioning plan
- Review of installation and record documents
- Documentation of any deviation from the OPR and recording of any issues in an issues log
- Witness of pre-functional and acceptance testing
- Recommend acceptance of the system to the owner
- Submission of the final commissioning report to the owner

The commissioning plan, which should contain all elements of the activities of the commissioning team, normally includes the following information:

1. Commissioning scope and overview specific to the project
2. General project information as outlined in the OPR
3. Fire protection and life safety commissioning team members, roles and responsibilities
4. General communication plan and protocol
5. Commissioning process tasks and activities through all phases
6. Commissioning schedule
7. Required commissioning process documentation and deliverables
8. Required testing procedures
9. Recommended training
10. Establishment of a comprehensive operations and maintenance procedure

Because a commissioning agent will most likely oversee testing of interconnected systems, it is imperative that the commissioning team fully understands all aspects of the project in order to develop and execute the commissioning plan.

DESIGN PHASE

Much of the design phase of a project involving commissioning includes the development of a basis of design (BOD) document or narrative report in addition to the design. The BOD document is intended to provide project design details that may not be readily apparent in the design documents. The BOD should include the thought process used in the design as well as a thorough description of the proposed systems and how the systems are expected to work together. This description should also include an analysis of system interactions and how these interactions will impact the independent operation of the individual systems.

> The construction phase will require many coordination meetings and impromptu meetings in the field to schedule and complete verification of the installation and testing.

As the industry moves forward with more performance-based design versus prescriptive design, a detailed description of systems and their interaction will become even more necessary. Because this is performance-based design, without this detailed information, it will be impossible to determine what the design intent was initially. This would not necessarily be an issue with prescriptive design. The BOD should contain the following elements:

1. A description of the building or structure
2. A description of the proposed systems and components
3. Performance objectives and criteria
4. Codes and standards used
5. Acceptance testing and other startup requirements
6. Inspection, testing and maintenance requirements

The BOD should be prepared and submitted for review concurrently or prior to any design drawings or calculations. The information contained in the BOD is essential for a complete understanding of the function and design intent of the proposed systems. While this information is not necessarily required by any of the applicable installation codes or standards, it will be very useful during review of the design drawings and calculations.

For example, performance objectives and criteria may include a matrix of the system interactions intended by the design team. This is helpful because it is not always readily apparent what interactions are necessary when a sprinkler waterflow switch or a fire alarm smoke detector activates. While acceptance testing requirements are well established in each individual installation standard, the requirements for interconnected systems testing are not as widely known. The BOD can help explain the requirements for interconnected systems as well as many other design questions.

Integrated Systems. The design methodology for integrated systems should take into account a number of factors including what type of material and equipment are interconnected. The testing requirements for individual systems are very well established in each respective

Commissioning

installation standard but testing of the entire integrated system of sprinkler, smoke control and fire alarm is not addressed in any current code or standard. The testing of the final interconnection of all of these systems must be addressed and included in the BOD and should be managed by a formal commissioning program.

Additionally, the BOD should document how the interconnected systems operate and communicate to achieve the intended outcome and should clearly demonstrate that operation of interconnected systems does not impair the functionality of other systems or components unless intended to do so.

The sequence of operation of interconnected systems and location of interconnections should be delineated in the BOD including a procedure and frequency for testing because no code or standard currently requires such information.

CONSTRUCTION PHASE

Most of the commissioning activity takes place during the construction phase. The most important activities in this process are 1) witnessing and verifying compliance with the approved shop drawings and product data submittals by performing inspections of the installed systems and equipment and 2) witnessing and verifying pre-functional testing and acceptance testing of systems and components. Each of these activities must be documented with any identified problems or issues noted and the appropriate corrective action taken before occupancy.

The construction phase will require many coordination meetings in the field to schedule and complete verification of the installation and testing. The construction phase also includes compilation of the turn-over documentation or "as-builts" and initiation of the training program established in the commissioning plan.

An important part of commissioning is the development and submittal of project closeout documentation. Not only must a complete and accurate set of as-built drawings and calculations be included in this submittal, but a copy of all test reports and a comprehensive list of materials, equipment and contact information for equipment suppliers must be compiled. As a minimum, project closeout documents should include:

1. Compiled list of all deficiencies and resolutions including verification of corrective action

2. Operations and maintenance manuals
3. Documentation of test results and certificates
4. As-built drawings and calculations
5. Warranties
6. Recommended spare parts lists and supplier listings
7. Re-commissioning plan (periodic integrated testing)
8. Sequences of operation
9. Basis of design

OCCUPANCY PHASE

The occupancy phase occurs when construction is complete, acceptance testing is verified and documented and the final submittals, such as operation and maintenance manuals, are delivered. It is at this time that formal training of operating personnel is conducted. This is a critical aspect of commissioning since it is the operating personnel who care for the ongoing operation of the building and systems. Because many operating personnel may not be very well versed in the operation and maintenance or even the intended function of fire protection systems, training related specifically to these systems is especially important. Under the commissioning process, design documentation will also occur during the occupancy phase, hopefully eliminating the scenario where fire protection professionals need good documentation to redesign or update an existing system only to find that none exists.

THE FUTURE

If commissioning is simply an additional quality assurance checkpoint, why further add to the cost of the construction process with additional paperwork and another inspection? Formal commissioning addresses the scenarios where an installing contractor may not be prepared to test a system when the fire marshal arrives on site or individual contractors are either not prepared to, or do not understand the need to, test interconnected systems. Further, once construction is completed and the building is occupied, building owners often do not have the appropriate turnover documentation for the newly installed systems.

Commissioning is not intended for every project. A small project or one that is relatively straightforward only requires the submittal and acceptance testing requirements of the appropriate installation standard. Commissioning is designed for larger, more complex projects.

There are two main reasons why a building owner — who is funding the project — might consider

commissioning:

- The project is large and very complex and commissioning could provide a cost reduction by identifying inefficiencies through a best practices approach to construction.
- The project is undergoing Leadership in Energy and Environmental Design (LEED) or Green Globes certification, in which case commissioning is mandatory.

With the U.S. Green Building Council forecasting growth in LEED and Green Globes construction to double between now and 2013, more buildings will be required to complete a formal commissioning process in order to meet these certification standards. Perhaps this increase in commissioned projects will make the industry more comfortable with the commissioning process as well as streamline the process to make it less onerous.

Until then, building owners with projects that will not be certified to LEED or Green Globes will need to determine whether or not their project is "complex" enough to justify the time and expense associated with a formal commissioning process. A properly commissioned system can pay dividends over its service life by not needing as much maintenance and service as a system that was not the subject of a formal commissioning program.

As the industry moves forward towards commissioning, there are several organizations that are involved with and are proactive in the commissioning process.

The National Institute of Building Sciences (NIBS) is currently developing a set of 11 guidelines covering total building commissioning. These guidelines will include all aspects of a building and its systems.

ASTM International has assembled a working group (Task Group E06.55.09) to develop a *New Practice for Exterior Enclosure Commissioning*. This project is an expansion of part of the forthcoming NIBS guideline and translates that information into an enforceable standard.

The Portland Energy Council has developed a guideline[1] on commissioning. The U.S. General Services Administration (GSA) has published *The Building Commissioning Guide*[2] designed for project managers, commissioning agents and other stakeholders in the commissioning process. The guide provides an overview of the commissioning process including planning, design, construction and post-construction phases of a project.

The Building Commissioning Association's (BCA) mission is to guide the building commissioning industry through advancing best practices and education and promoting the benefits of building commissioning. The BCA has many publications related to the commissioning of buildings and systems including the *Building Commissioning Handbook*.[3]

The National Fire Protection Association has published a book titled *Commissioning Fire Protection Systems*[4] and is presently developing a document on the subject. The draft document, although not complete as of this writing, should be available in 2011. The recommended practice, which has been under development since December 2007, presently includes recommendations for testing of interconnected systems with a sample testing matrix illustrating potential interactions of various fire and life safety systems in addition to all of the necessary elements for a comprehensive commissioning program.

So is commissioning a new buzzword? No, commissioning is nothing more than a best practices or project management effort that FPEs have been engaged in for a long time. Commissioning is a quality assurance or quality control process that verifies completion of work as specified in either the project specifications or codes and standards (or both). A formal commissioning program may require documentation in excess of the norm or pre-functional testing in excess of the minimum code requirement but commissioning is nothing new.

The basic objectives of commissioning are to clearly document the needs of the building owner, provide an organized, documented approach to verification of deliverables, better documented and more detailed verification of system performance, improved training of personnel and vastly improved turn-over documentation. This best practices approach, complete with better documentation, is the very foundation of commissioning.

David Hague is with Liberty Mutual Property Risk Engineering.

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2 *The Building Commissioning Guide*, U.S. General Services Administration, Washington, DC, 2005.

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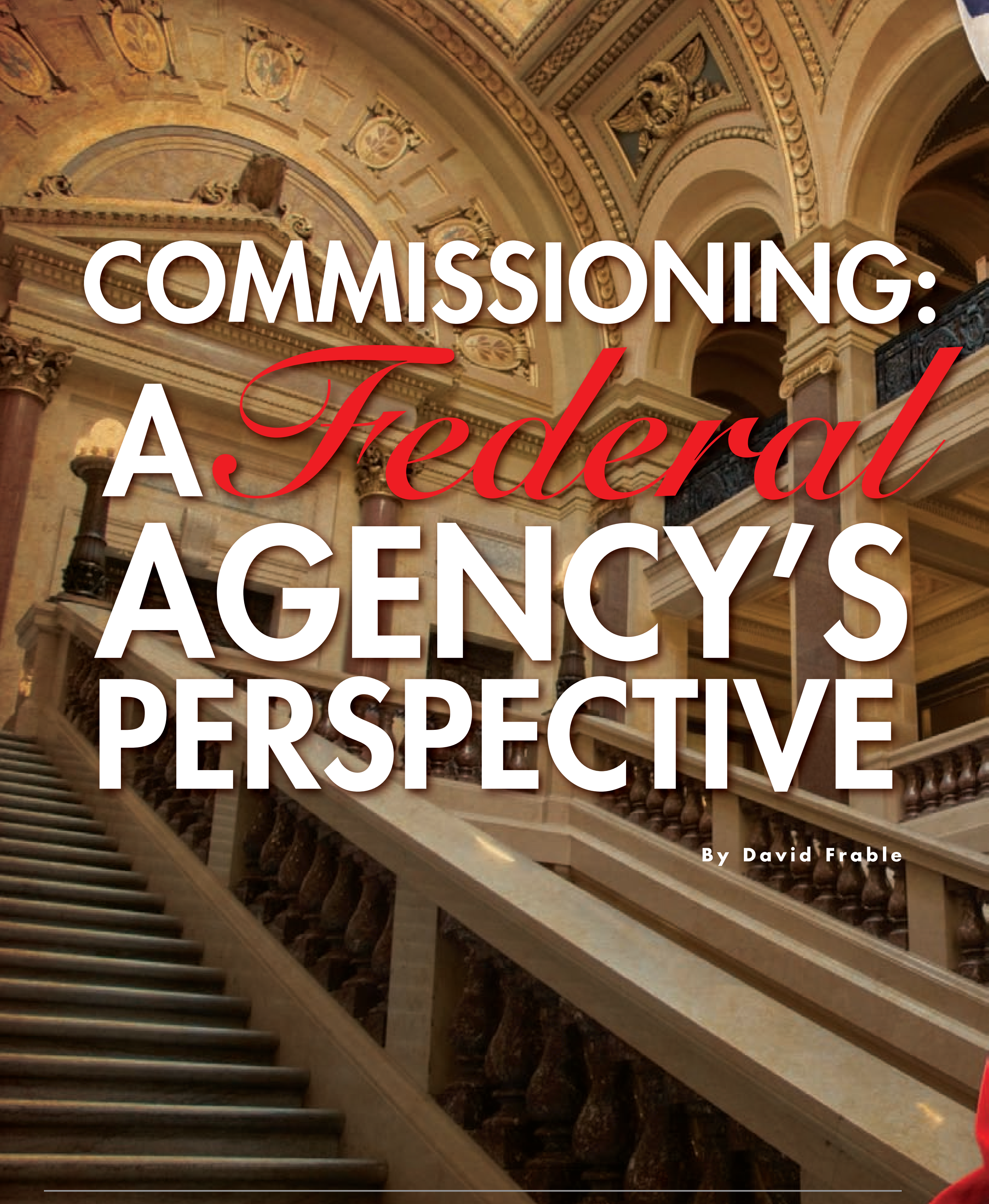

COMMISSIONING: A *Federal* AGENCY'S PERSPECTIVE

By David Frable

WHAT IS "COMMISSIONING"?

"Commissioning", aka "Cx," is probably one of the most used words and acronyms being incorporated into commercial building construction projects today. For example, an Internet search for the term "commissioning" yields over 13 million responses. In addition, organizations such as the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE), National Institute of Building Sciences (NIBS), U.S. Department of Energy (DOE), U.S. Green Building Council, American Institute of Architects (AIA), and U.S. General Services Administration (GSA) all have embraced "commissioning" to one degree or another.

Traditionally, the term "commissioning" in commercial building construction projects has referred to the process by which the building heating, ventilation and air conditioning (HVAC) systems were tested and balanced prior to the system being accepted by the building owner. However, today's use of the term "commissioning" now recognizes the integrated nature of all building systems' performance and not just HVAC system performance. In addition, commissioning is now required for any project that is considered for Leadership in Energy and Environmental Design (LEED) certification or Green Globes certification.

Although there are numerous definitions for commissioning, GSA has defined "commissioning" based on the definition of the National Conference on Building Commissioning (NCBC):

> *"Systematic process of assuring by verification and documentation, from the design phase to a minimum of one year after construction, that all facility systems perform interactively in accordance with the design documentation and intent, and in accordance with the owner's operational needs, including improved training of building operation personnel."*[1]

In layman's terms, commissioning is a quality assurance and control process that provides the necessary documentation to the building owner that verifies the systems installed will perform as intended in accordance with the project's requirements. The process also ensures that the owner's personnel will be thoroughly trained in both the routine and emergency operation of all the building systems.

WHY HAS GSA EMBRACED COMMISSIONING?

GSA's Public Buildings Service (PBS) is the landlord of the civilian government for over 400 federal agencies, bureaus and commissions. GSA houses in excess of 1 million federal employees in approximately 1,500 government-owned and 8,100 leased assets in approximately 2,100 communities throughout the United States, six U.S. territories and the District of Columbia; and has an on-going planning, design and construction program to meet the needs of federal agencies.

One of GSA's responsibilities is to provide federal agencies with efficient, safe, secure and sustainable commercial space. Integrating total building commissioning into GSA's construction project delivery process provides one way for GSA to meet and exceed customer expectations. Total building commissioning also provides a means for meeting the intent and requirements contained within GSA's design criteria document, the *GSA Facilities Standards for the Public Buildings Service*[2] *(PBS-P100).*

> *The PBS-P100 establishes design standards and criteria for all new buildings, major and minor alterations, and renovations in GSA's historic building inventory. PBS-P100 also includes a chapter specifically dedicated to fire protection and life safety, which contains an outline of the procedures, methods and documentation that is required for fire protection and life safety systems during each phase of the commissioning process.*

As building systems become more complex and integrated, a deficiency in one or more system components may result in substandard operation and performance among other building system components. Therefore, reducing the number of deficiencies can result in a variety of benefits such as reduction in operating costs, improved energy efficiency, improved occupant safety, improved comfort and health, and increased maintainability of systems.

In April 2005, GSA published *The Building Commissioning Guide*[1] (Guide) to provide project managers, construction managers and consultants with a vehicle to navigate through GSA's commissioning process. According to PBS-P100, all new construction and major modernization projects are required to utilize the total building commissioning practices. The overall objective of GSA's commissioning process is to provide documented confirmation that a building fulfills the functional and performance requirements within PBS-P100.

The Guide also describes general information regarding each phase of the commissioning process as well as examples of the roles and responsibilities of each stakeholder on the project team to support the overall commissioning of a project.

OVERVIEW OF GSA'S COMMISSIONING PROCESS

GSA's commissioning process consists of four phases: planning, design, construction and post construction.

Therefore, it is necessary for the commissioning process to establish and document the project requirements which specify the criteria for each building system function, performance and maintainability; and to also verify and document compliance with these criteria throughout each phase of a project. In addition, the commissioning process will provide complete operation and maintenance manuals and training on the operation of each building system, so building operators can ensure their building will continue to operate as intended.

PLANNING PHASE

The planning phase lays the groundwork for the commissioning process. It is the critical phase where GSA's project requirements are developed in order to establish and document the owner's project requirements and criteria for the building system's function, performance and maintainability. The major steps of the planning phase include:

- Identifying the commissioning team
- Developing GSA's project requirements with all stakeholders
- Developing the preliminary commissioning scope
- Developing the preliminary commissioning plan
- Establishing the initial budget for commissioning activities

The Guide states:[1]
The first step of the planning phase is to identify the make up of the commissioning team. The exact size and number of members of the commissioning team will vary in size depending on project type, size and complexity. Generally, the team will consist of:

- *GSA project manager*
- *GSA operating personnel*
- *GSA technical experts (i.e., structural, mechanical, fire protection, electrical, etc.)*
- *Federal tenant agency representative(s)*
- *Architect/Engineer*
- *Commissioning Agent – also referred to as Commissioning Authority*
- *Construction Manager*
- *Construction contractor and subcontractors*

DESIGN PHASE

The design phase is where the project design team creates the construction documents in accordance with the owner's projects requirements for items such as energy efficiency, sustainability, indoor environmental quality, fire protection and life safety, etc.[1] The design phase is also the commissioning team's opportunity to assure that building systems, as designed, will function according to user expectations. During this phase, specific tests and procedures need to be developed and incorporated into the contract documents to verify the performance of systems and assemblies. The major steps within the design phase include:

- Incorporating commissioning into Architect/Engineer (A/E) and Construction Manager (CM) scope of services
- Retaining the services of a Commissioning Agent (CxA)
- Reviewing the owner's project requirements and basis of design
- Reviewing concept designs, design documents and construction documents
- Updating the commissioning plan
- Developing/updating the LEED checklist
- Developing the commissioning specifications, which include written system test procedures and operator training requirements

It should be noted that, based on past experience, "maintainability" of building system components is sometimes overlooked by design team architects/engineers. For example, maintaining lighting units, smoke detectors, fire sprinklers, exhaust fans, etc., installed at the ceiling level of an atrium may be difficult to access and thus hamper necessary preventive maintenance. Developing solutions to address "maintainability" issues at the post-construction phase can become very costly for the building owner. Therefore, it is essential that the CxA and design team address "maintainability" issues during this phase of the commissioning process.

CONSTRUCTION PHASE

The construction phase is the phase most associated with commissioning. However, if the previous phases and activities have not been implemented prior to this phase, it could adversely impact the entire commissioning process.

During the construction phase, the commissioning team should work to verify that systems operate in a manner that will achieve the owner's project requirements.[1] The two overarching goals of the construction phase are to assure the level of quality desired and to assure the requirements of the contracts are met by completing installation, functional performance testing and training to ensure documented system performance in accordance with the owner's project requirements. Functional performance testing and documentation during this phase will also serve as an important benchmark and baseline for future re-commissioning of the facility. The major steps of the construction phase include:

- Reviewing submittal documents which include coordination drawings, redlined as-built drawings, product data and key operations data submittals, system manuals, operation and maintenance manuals, and training programs
- Developing and using construction checklists
- Overseeing and documenting functional performance testing of building systems
- Holding commissioning team meetings and report progress
- Conducting O&M staff training

The functional performance tests are the heart of the commissioning process and they are also the most difficult and time consuming. System troubleshooting is a critical function of the CxA. As inspecting and testing proceed, despite the team's best efforts, the CxA will find a number of


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items that do not appear to work as intended. A certain amount of system retesting will be performed by the CxA because of system deficiencies during the initial testing. In order to assure success, the GSA PM shall allow some time in the schedule and money in the budget for retesting. The GSA PM shall be apprised that issues resolution and associated financial implications are a common point of contention between parties.[1]

Another area of concern involves the training of the owner's representatives and O&M staff regarding a building's fire protection and life safety systems. The owner's operations and maintenance staff must be properly trained to understand the operation of all fire protection and life safety equipment, systems, operational sequences and how they are integrated with other building systems. For example, the O&M staff may be assigned to operate the building's fire alarm emergency communication system to broadcast emergency information to the building occupants. However, if the O&M staff is unfamiliar with the operation of the fire alarm emergency communication system and that the system has the capability to broadcast messages either throughout the building or only selected floors within the building, misdirected information could be disseminated without the knowledge of the O&M staff.

POST-CONSTRUCTION PHASE

The objective of the post-construction phase is to maintain building performance throughout the useful life of the building or systems. The active involvement of the CxA and the commissioning team during initial facility operations is an integral aspect of the commissioning process. The major steps of the post-construction phase include:

- Resolving outstanding issues
- Performing deferred and seasonal testing
- Re-inspecting and reviewing system performance prior to the end of the warranty period
- Completing the final commissioning report
- Performing a post-occupancy review with the appropriate stakeholders
- Developing a plan for re-commissioning the building or systems throughout their life cycles

It should be noted that due to project timing, not all building systems can be tested to verify they will operate and function properly during all seasonal weather conditions prior to completing the construction phase. For example, an exit stair pressurization system in a 42-story commercial office building should be tested to verify that it will operate and function as designed during both winter and summer. For this reason, commissioning plans should include seasonal testing provisions to allow for testing of certain equipment under all possible conditions. In these cases, the commissioning team should document these types of issues such that

all deferred testing is scheduled and completed. In addition, requirements for deferred and seasonal testing must be clearly defined in the contract documents as it will require contractor personnel to return to the site after the project is completed.

GSA COMMISSIONING CONTRACTS

GSA currently has a national commissioning contract in place that consists of three small business consultants and four unlimited size consultants. All the firms have professional expertise in fire protection engineering. GSA has approximately 200 active commissioning projects ongoing throughout the United States.

ROLE OF GSA FIRE PROTECTION ENGINEERS

GSA fire protection engineers have always played a vital role in ensuring that all projects have their fire protection and life safety systems reviewed, designed, constructed, tested, and maintained in accordance with PBS-P100 as well as national codes and standards. In addition, they are also responsible for issuing certificates of occupancy for GSA projects. Prior to issuing a certificate of occupancy, all outstanding significant fire and life safety deficiencies that have been documented during construction or operations must be corrected to afford a reasonable degree of safety to the building occupants from fire risks and similar emergencies.

GSA fire protection engineers will also verify the functional performance and integrated testing of 100 percent of the fire protection and life safety system components, including their interconnections and associated interaction with other building systems (e.g., elevator shunt trip, door hold-open devices, smoke control systems, egress door security locking arrangements, etc.) to ensure they operate in accordance with the design and code requirements. This is because fire protection and life safety systems can sometimes operate equipment that is not a direct component of the fire protection and life safety system. However, other building systems that are commissioned may not require integrated testing – such as building lighting system motion detectors – yet only require functional testing verification of 10–20 percent of the components.

CRYSTAL-BALLING GSA COMMISSIONING ACTIVITIES

The fire protection and life safety chapter in the next edition of PBS-P100 will likely have a revised section on commissioning fire protection and life safety systems. This new section may include a requirement that the commissioning team must also retain the services for a fire commissioning agent (FCxA).The new section would state that the FCxA also be separate, both by contract and by employment, from the A/E design team, and also acknowledge that the skill sets of the FCxA are different than the skill sets of the CxA; just as the skill sets necessary to perform the commissioning activities for the HVAC systems are different than the commissioning activities associated with the fire protection and life safety systems. In addition, the FCxA would be responsible to perform all the applicable fire protection and life safety commissioning activities.

Lastly, it should be noted that the National Fire Protection Association (NFPA) has embarked on a new project for developing a standard that addresses the commissioning process for fire protection and life safety systems. The NFPA 3, Technical Committee on Commissioning Fire Protection Systems, is responsible for documents pertaining to commissioning activities for fire protection systems. GSA is one of many organizations serving on this technical committee.

David Frable is with the U.S. General Services Administration.

References:

1 *The Building Commissioning Guide*, United States General Services Administration, Public Building Service, Washington, DC: 2005.

2 *Facilities Standards for the Public Buildings Service*, PBS-P100. United States General Services Administration, Public Building Service, Washington, DC: 2005.

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LESSONS LEARNED FROM UNSATISFACTORY SPRINKLER PERFORMANCE:

An update on trends and a root cause discussion from the investigating engineer's perspective

By R. Thomas Long, Jr., P.E.,
Neil P. Wu, P.E.,
and Andrew F. Blum

Automatic sprinkler systems are often considered the most significant component of a building fire protection strategy. When properly designed, installed and maintained, an automatic sprinkler system can control a fire and significantly reduce deaths, injuries and property damage. However, sprinkler systems have their limitations, and their performance can be affected by factors not linked to the initial design or installation of the sprinkler system. This article explores automatic sprinkler system failure data to identify and discuss causes of unsatisfactory sprinkler performance.

Historical fire losses provide experiences that shape current fire protection design methodologies, design criteria and defense strategies. Significant lessons learned have been extracted from post-fire investigations of major losses of life and/or property despite protection by an automatic sprinkler system. These post-fire loss investigations revealed not only the cause of the fires, but causes associated with unsatisfactory sprinkler system performance. Unsatisfactory performance includes failure to operate, as well as ineffectiveness to control a fire and limit damages to life and property.

Generally, sprinkler systems are considered reliable[1] and effective when properly designed, installed and maintained. Research shows that between 2003 and 2007, sprinklers operated in 93% of all fires large enough to cause actuation and were effective in 97% of the fires in which they operated.[2] However, buildings are dynamic, and in the modern era of design flexibility, structures are increasingly subject to changes in characteristics, use and function. Over time, new tenants replace old ones, walls may be removed, added or altered, protected commodities can change, and sprinkler systems may require modification. From its initial installation, the sprinkler system waits patiently through the changes, and perhaps someday in the event of a fire, will have an opportunity to spring into action. What occurs to the protected occupancies and the system after the initial installation, up to the time of a fire, can have a profound impact on sprinkler system effectiveness.

An investigating fire protection engineer may determine why the sprinkler system did not control the fire or otherwise perform as intended, as well as evaluate how these factors affected the outcome of the fire and the overall ineffectiveness of the sprinkler system. This information is of value to the fire protection community, as knowledge of past mistakes can create awareness and possibly help to prevent repeat failures.

This article highlights specific root causes that lead to unsatisfactory performance through the examination of past fire loss data across a broad range of occupancies. Specific examples of fires where sprinkler systems failed to perform as intended are presented.

SPRINKLER SYSTEM PERFORMANCE BY THE NUMBERS

A review of historical sprinkler system statistics reveals common failure modes of sprinkler systems. The National Fire Protection Association (NFPA) publishes data summarizing sprinkler system performance in the United States on a frequent basis. From 1925 through 1969, the top five reasons for unsatisfactory sprinkler performance were:[3]

1. Water shut off (35.4%)
2. System not adequate for level of hazard in occupancy (13.5%)
3. Inadequate water supplies (9.9%)
4. Inadequate maintenance (8.4%)
5. Obstruction to water distribution (8.2%)

Other reasons for unsatisfactory performance included: partial sprinkler protection (8.1%); faulty building construction (6.0%); system components defective or damaged (5.6%); exposure fire (1.7%); system frozen (1.4%) and other (1.9%). Examining the most recent statistics,[2] similar causes of unsatisfactory sprinkler system performance persist. The top five reasons that sprinkler systems failed to operate or were ineffective during a fire were:

1. System shut off (38%)
2. Inappropriate system for the type of fire (18%)
3. Water discharged did not reach fire (12%)
4. Lack of maintenance (12%)
5. Problem with water supply or not enough water discharged (9%)

Other reasons for unsatisfactory performance included manual intervention defeated system (8%) and system component damaged (3%). Although the categories used to quantify unsatisfactory performance have evolved over time, the common themes remain the same.

Examining the 35 reported large-loss fires in the United States in 2008,[4] (large-loss being defined by the NFPA as a fire or explosion event of at least $10 million) large-loss fires caused an estimated $2.34 billion in damages, killing 15 civilians, injuring 60 civilians and 32 firefighters. Of these 35 large loss events, 31 involved structure fires (the other four were wildland fires).

Information regarding automatic suppression equipment was reported for 21 of the 31 structure fires. Eleven of the 21 fires were provided with some type of suppression system. Eight of these 11 systems operated (73%). Six of the eight systems (75%) were not effective in controlling the fire, while the effectiveness of one was not reported and only one system was effective in controlling the fire in its coverage area (see Table 1).

As evidenced by the most recent large-loss fire data, sprinkler system problems can be a significant contributing factor to large-loss fires.

REASONS SPRINKLER SYSTEMS FAIL TO CONTROL THE HAZARD

As described in the data above, the NFPA has catalogued a number of reasons that commonly contribute to unsatisfactory sprinkler system performance. The following is a list of major categories that summarize why sprinkler systems are ineffective in controlling fires and the root causes for unsatisfactory sprinkler system performance.[3]

1. **Failure to maintain operational status of the system.** The foundation of achieving satisfactory sprinkler performance is regular inspection, testing and maintenance of the sprinkler system and providing a system that is 100% operational before and during a fire event. This category includes instances where the water supply is shut off for any number of reasons prior to or during the fire event (i.e., manual intervention during firefighting activities), inadequate maintenance (including installation deficiencies not captured during acceptance testing or subsequent inspection, testing and maintenance procedures), component mechanical or corrosion failures, and obstructions to water distribution.
2. **Failure to assure adequacy of system and/or for the complete coverage of current hazard.** The effectiveness of a sprinkler system starts with proper design and installation of the system for the given hazard. This category encompasses instances where the unsatisfactory performance of the sprinkler system was caused by the inability of the sprinkler system to apply

Table 1. 2008 Large-loss fire data[5]

Category	Number	Percentage
Structure Fires	31	88.6%
Wildland Fires	4	11.4%
Total Large-Loss Fires	**35**	**100.0%**
Automatic Suppression System	11	35.5%
No Automatic Suppression System	10	32.3%
No Automatic Suppression Information Reported	10	32.3%
Total Structure Fires	**31**	**100.0%**
Suppression System Operated	8	72.7%
Suppression System Did Not Operate	1	9.1%
Suppression System Operation Not Determined	2	18.2%
Total Automatic Suppression Systems	**11**	**100.0%**
System Ineffective in Controlling the Fire	6	75.0%
System Effective in Controlling the Fire	1	12.5%
System Effectiveness Not Reported	1	12.5%
Suppression Systems Operated	**8**	**100.0%**
System Not in the Area of Origin	3	50.0%
System Operated But Damaged By Explosion	1	16.7%
Fire Load Greater Than Suppression System Design	1	16.7%
System Operated But Shut Off For Unknown Reason	1	16.7%
System Ineffective in Controlling the Fire	**6**	**100.0%**

enough water to control the hazard it protects, and includes initial design errors, partial system installations, installation mistakes, changes to the commodity (i.e., type, configuration or quantity), and/or changes to the building (i.e., its configuration, use or occupancy).

3. **Defects affecting, but not involving, the sprinkler system.** By design, the proper operation of a sprinkler system during a fire may depend on the function of other building systems and features. This category captures instances where unsatisfactory performance of the sprinkler system during a fire event was caused by conditions or elements that are peripheral to, but not distinctly a part of, the sprinkler system. Examples of causes include reductions in available water supply to the protected building, faulty building construction and lack of compartmentation.
4. **Inadequate performance by the sprinkler system itself.** The proper operation of a sprinkler system during a fire depends on proper operation of the components. Although considered reliable, sprinkler system components can fail and adversely affect the operation of the entire system. Data has shown that these types of failures are a very small fraction of the overall reasons for failure.

Other causes that contribute to unsatisfactory performance of sprinkler systems include: exposure fires starting on the exterior of the building; delays associated with manual fire suppression efforts; general delays in notifying the fire department of a small incipient fire that rapidly grows to a catastrophic size; and other unknown causes. These causes are a relatively small fraction of the reported reasons for unsatisfactory sprinkler system performance.

FAILURES TO MAINTAIN OPERATIONAL STATUS OF THE SYSTEM (#1)

Maintaining the water supply is the fundamental key to overall sprinkler system performance. A sprinkler system without adequate water supply (water pressure, flow and duration) is not likely to provide satisfactory performance. Data has shown that lack of an adequate water supply is a primary contributing factor to unsatisfactory sprinkler system performance. Water supplies can be shut off for any number of reasons, including maintenance, vacant structures, to allow for firefighting operations, building construction or demolition, and system impairments such as leaks, pipe obstructions, obstructions to sprinkler distribution, closed valves, etc. A closed water supply valve is the most common cause of system impairment.

Case Study: A July 2007 fire in Massachusetts caused approximately $26 million in damages. The fire occurred within a three-story former mill building of unprotected construction that was used by 56 mercantile businesses and covered 350,000 square feet (33,000 square meters). The fire was believed to have started after welding was completed in the basement the day before. The building was closed at the time of the fire. A full-coverage combination wet- and dry-pipe sprinkler system was provided and was located in the area of fire origin. However, a sprinkler valve in the area of origin was closed and padlocked. With the water supply shut off, the fire was able to spread and quickly overwhelm the rest of the sprinkler system. No notice of the system shutdown had been provided to the fire department.[6]

Even if an adequate water supply is provided, manual interruption of the water supply during a fire event can have catastrophic results. Fire department interruption of a sprinkler system removes the sprinkler system from the protection equation and renders the system ineffective. Turning off a sprinkler system will allow the fire to grow and cause the activation of additional sprinklers. If the system is restored later in the fire, it is possible that sprinklers outside of the design

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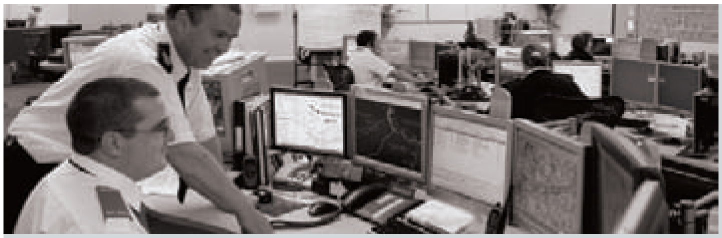

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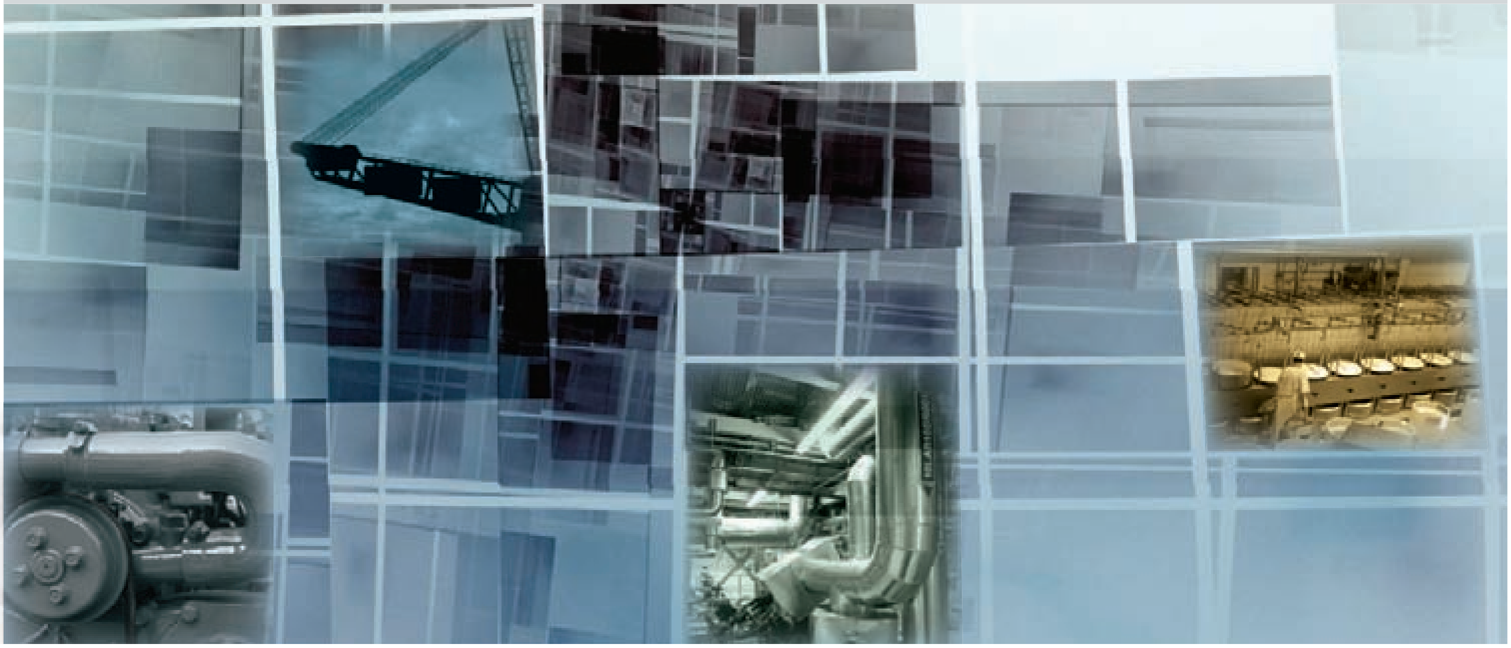

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Inadequate sprinkler system inspection, testing and maintenance can render a properly designed and installed system ineffective. NFPA 25[8] provides required inspection, testing and maintenance for a sprinkler system. If systems are not periodically inspected for mechanical deficiencies, proper function, valve actuation, water flow, sprinkler clearances, etc., the system may not be effective during a fire.

Case Study: A fire in a Georgia textile recycling plant in January 2007 caused $7.5 million in damages and killed one civilian, despite the presence and operation of the installed sprinkler system. The plant was 245,000 ft^2 (23,000 m^2), three-stories high and was built of heavy-timber construction. Due to an unknown cause, a fire broke out in a machinery room of the plant and spread to the rest of the plant, activating over 75 sprinklers. The sprinkler system was ineffective in controlling the fire, as it had not been maintained for quite some time. Maintenance deficiencies included improper sprinkler clearance, sprinkler risers modified to allow the use of garden-type hoses, and valves not fully open.[7]

Fire protection codes and standards provide multiple ways to verify the open status of valves, including tags and electronic valve supervision systems connected to the building fire alarm system. Training as to what precautions should be taken in off-normal conditions, as well as communicating impairment protocols, is part of maintaining the system in an operational status. In general, a flowing sprinkler system in an emergency situation will provide better protection than a sprinkler system that is turned off or otherwise manipulated. Fire suppression efforts should work in conjunction with automatic sprinkler systems. Firefighting professionals should confirm that the fire is extinguished and there is no threat of a fire spreading before shutting off automatic sprinkler systems.

FAILURES TO ASSURE ADEQUACY OF SYSTEM AND/OR THE COMPLETE COVERAGE OF CURRENT HAZARD (#2)

A sprinkler system's effectiveness during a fire event is bound by the design criteria of the original installation. The design criteria must be consistent with the protected hazard. A common cause of unsatisfactory sprinkler system performance is inappropriate design for the hazard protected. The inadequacy of a sprinkler system could stem from a number of reasons, including initial design errors, installation deficiencies, partial system designs, changes to the protected commodity in its configuration/quantity, and building changes in use or occupancy.

Case Study: In 2008, a fire ignited accidentally by roofers occurred in an outdoor film studio consisting of unprotected wood frame façades constructed to mimic the narrow streetscape of New York City. The façades were in close proximity to one another and were protected with a deluge sprinkler system. The system operated during the fire; however, it was unable to control the fire due to the amount, distribution and orientation of available fuels. The fire quickly spread through the façades and involved adjacent buildings and structures. As the fire spread, the façades collapsed and deluge riser failed, reducing the effectiveness of the deluge system. The deluge sprinkler system's inability to control the fire and the large fuel load, among other factors, was a factor in the fire's rapid spread and estimated $38 million in damage.[4, 7]

Changes in the protected hazard, the sprinkler system or the structure itself can occur throughout the life of a building and may not be evaluated with respect to the existing sprinkler system capabilities. Whether intentional or performed out of ignorance, the result can be catastrophic. As structures change (e.g., change in tenant, ownership, operation; change in walls, ceilings or floors; change in storage), the sprinkler system, as initially designed and installed, may be inappropriate for the protected hazard. The annual inspection required by NFPA 25[8] includes a review of the hazard(s) to verify the system design remains appropriate for the

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hazards and use of the building. This is an important item needed for successful performance.

Seemingly minor changes in the protected hazard can significantly impact the sprinkler system's ability to effectively control a fire. Sprinkler systems that are not adequate to protect the stored commodities or where the fire load is too large for the system design have contributed to large losses in several instances. These include a 1999 Georgia warehouse fire (damages $7.3 million); a 1998 North Carolina warehouse fire (damages $32 million); and a 1996 Michigan rolled paper and chemical warehouse (damages $14 million).[9]

Seemingly minor changes in the protected hazard can significantly impact the sprinkler system's ability to effectively control a fire.

Case Study: A March 1998 fire at a bulk retail store in Tempe, AZ, resulted in more than $6 million in damage to the building and contents. The store, originally built in 1988, was a one-story masonry structure with a footprint of 400 x 250 ft (120 x 76 meters) and a height of 24 to 29 feet (7.3 to 8.8 meters). It was equipped with a partial in-rack sprinkler system not involved in the fire and had a ceiling-level automatic sprinkler system designed to protect a Class IV commodity throughout. At the time of the fire, the store primarily housed Class A expanded and unexpanded plastics, a hazard that does not match the level of protection provided. Although the sprinkler system did play some role in slowing the fire spread, it activated 2.5 times more sprinklers than the system was designed to supply, and did not stop flames from spreading across 10 foot (3 meter) aisles. Among other contributing factors, the change in the commodity without reevaluating the installed sprinkler system played a large role in the fire spread and damage to the building.[10]

Fires originating in unprotected areas, such as concealed spaces, voids or areas beyond the protection area of sprinklers can be catastrophic. A fire originating in an unprotected space can grow unchecked, eliminating the opportunity for the sprinkler system to operate and protect the hazard while the fire is still relatively small. Consequently, once the fire spreads into the protected area, the sprinkler system can be overwhelmed by the fire's size and is unable to control the fire.

Case Study: In November 2008, a fire occurred in a 114-unit, one- and two-story unprotected wood-framed motel and overwhelmed the wet-pipe sprinkler system. The fire originated in an unprotected (i.e., non-sprinklered) attic space and spread across the attic and down into the protected motel lobby and guest rooms. The sprinkler system was unable to control the fire once it spread into the protected area, and ultimately the ceiling and roof collapsed, further complicating fire suppression efforts. The fire caused an estimated $10 million in damages.[4]

The hazard protected must be within the designed capability of the sprinkler system. If changes to

the protected hazard are made after the original installation of the sprinkler system, an evaluation of the potential effects must be considered. Incomplete coverage by a sprinkler system can result in vulnerability of the system effectiveness. The absence of sprinklers may allow for a fire to grow to a size that can overwhelm the systems installed in protected areas. Although some sprinkler system installation standards may allow for exclusion of sprinkler protection in particular locations, a comprehensive risk analysis can be used to weigh the potential consequences for incomplete sprinkler system coverage.

DEFECTS AFFECTING, BUT NOT INVOLVING THE SPRINKLER SYSTEM (#3)

Sprinkler system designs are premised on the principle that the strength of the water distribution system available at the time of construction will remain within the original design buffer. However, the water supply strength can degrade over time. Increased nominal demand from new developments utilizing the same water infrastructure, closing of water infrastructure isolation valves and seasonal effects can result in diminished flow and/or pressure available to sprinkler systems. Water authorities may reduce water infrastructure working pressure to conserve water that is wasted due to leakage.

Defective building construction can render a sprinkler system inoperable. A common occurrence is the collapse of a building element used for support of sprinkler system components during a fire. The failure of a joist, beam, roof section or floor during a fire can rupture sprinkler system pipes, causing a loss of water pressure to the system and unsatisfactory performance of the sprinkler system.

Case Study: In July 2002, a 61,600 ft^2 (5,700 m^2), 110 foot (34 meter) high Wisconsin magazine printing plant suffered a building collapse and subsequent fire, causing approximately $17 million in damage. The plant, built of unprotected non-combustible construction and protected by a complete coverage wet-pipe sprinkler system, was in full operation when the building collapsed and the fire started. During the building collapse, the sprinkler system and sprinkler risers were damaged and rendered useless; the subsequent fire burned through the remainder of the plant rapidly.[2]

Compartmentation of hazards through the use of fire barriers and walls is a fire protection strategy in itself, but physical separations can play a role in the effectiveness of the sprinkler system. Higher hazard areas in buildings can be segregated by fire-resistance-rated construction. The concept is to contain the fire in the compartment and prevent spread outward.

Defects associated with building elements or other protection features can have an impact on sprinkler system performance. The attachment of sprinkler system components to building elements for support and restraint should be selected with care during the design and construction process. Vigilance is necessary in maintaining passive fire protection compartmentation, not only to prevent the spread of fire, but to also improve the

effectiveness of the sprinkler system in the area of fire involvement.

INADEQUATE PERFORMANCE BY THE SPRINKLER SYSTEM ITSELF (#4)

Although rare, components of the sprinkler system itself (sprinklers, piping, valves, etc.) can either fail to activate, delay activation or decrease the available water supply needed to effectively control the fire. System component damage is the least frequently cited reason for unsatisfactory sprinkler system performance. This is consistent with the earlier statements that overall sprinkler system components are reliable. The data presented involving component damage of sprinkler equipment included incidents where the damage was a consequence of the fire, rather than a root cause of sprinkler system failure.[2]

Tom Long, Neil Wu and Andrew Blum are with Exponent Failure Analysis Associates.

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Marriott's INSPECTION PROGRAM

By Stacy Welch, P.E.

On February 23, 1991, a legendary fire occurred in Philadelphia at One Meridian Plaza.[1] The fire raged for more than 19 hours, cost the lives of three firefighters and an estimated $100 million in direct property loss. A contributing factor to this disaster was incorrect settings on the pressure reducing valves on the standpipes. The firefighters were unable to get the water pressure they needed for the hose lines to operate effectively. If the pressure reducing valves had been inspected and maintained to verify the proper settings, the loss may not have been as great. Regular inspections and maintenance are vital to the effectiveness of life safety systems.

Marriott International Inc. has long realized the importance of regular inspections and maintenance. The ultimate goal is to protect their guests, associates and facilities. A large investment is made on active and passive fire protection systems during construction and it is logical to protect that investment for the life of the building.

Marriott's staff is fully involved in the design and construction of new hotels, and their design standards incorporate requirements to facilitate proper testing. They have learned that if system components are not easily accessible or not configured for convenient testing, the likelihood of testing or inspecting as required is greatly reduced. Marriott also realizes that its responsibility does not end when the first guest enters a hotel.

"DON'T EXPECT WHAT YOU DON'T INSPECT."

This phrase was a belief of J. Willard Marriott, the founder of Marriott International. He wanted to be on the ground checking quality and talking to associates. That business philosophy is reflected in the company's commitment to fire protection.

In 1991, Marriott began a program using two of its associates to provide annual fire protection inspections and staff training at Courtyard by Marriott hotels around the U.S. Marriott was fortunate to have the ability to launch the inspection program from their corporate fire protection department. The objective was to provide inspections that would meet applicable fire code and fire protection standards and add value by performing a comprehensive check of the hotel and by providing training to facility staff. In addition, providing corporate inspections contributes to consistency, uniform reporting and assurance of inspector competency—objectives that could not be achieved using multiple vendors. Today, the inspection program has expanded to all of Marriott's 17 brands, nearly 1,000 hotels annually with a staff of 20 inspectors.

The objective was to provide inspections that would meet applicable fire code and fire protection standards.

One key to the success of the Marriott inspection program has been hiring the right people to do the job. Prior to joining Marriott, each inspector has had a successful career in the fire service. The broad experience they gained at all levels of fire department operations, code enforcement and management proves invaluable. They have seen first-hand the systematic failures that lead to disaster and can apply those lessons to Marriott facilities on a daily basis. In addition, all Marriott inspectors are NFPA-certified as a Fire Inspector I and II and each goes through extensive in-house training prior to performing inspections. The inspectors are also supported by a staff of fire protection engineers, mechanical engineers, certified fire protection specialists and administrative associates.

Another strength of the program is the corporate environment that promotes cooperation between departments within Marriott International including global safety and security, engineering and facilities management, operations and quality assurance. The departments work together toward the common goal of safety and security. For example, if a fire door is damaged and does not close properly, each of these groups is responsible for identifying it. This provides a redundancy and an added layer of protection. Ultimately, the general manager and the building engineer are responsible for providing maintenance and repairs. Part of their annual performance review is tied to how well this is done.

The engineer is responsible for maintaining 30 to 200 pieces of equipment, some of these specific to fire protection and safety and each with different tasks at varying frequencies. Marriott's engineering and facilities management department has a program in place to trigger work orders for the hotel building engineer when maintenance is due. This system has proven effective to ensure maintenance is performed on schedule, for planning of equipment replacement and to ensure regulatory requirements are met. The equipment and maintenance records are checked by above-property engineering and facilities management representatives, as well as by regular quality assurance audits.

LESSONS LEARNED

Marriott has experienced some significant losses in recent years. In the World Trade Center attacks of 1993 and 2001 as well as bombings at the JW Marriott and the Ritz-Carlton in Jakarta last year, exiting capacity was reduced by up to 50%. Marriott was also affected by hurricane Katrina in 2005 – many hotels suffered extensive damage, and despite operating on emergency generators with minimal resources, some hotels in the Marriott system were used as safe havens until everyone could be evacuated. Each of these cases reinforced Marriott's understanding of the importance of fire protection systems functioning optimally at all times because when crisis strikes one or more systems is likely to be impaired.

THE MARRIOTT INSPECTION

The Marriott inspection includes annual testing of the fire alarm system and wet-pipe sprinkler system in addition to

a check of weekly, monthly and quarterly inspection and testing records. Testing of the dry, pre-action or anti-freeze sprinkler systems, fire pump, kitchen hood suppression systems, backflow preventors and fire extinguishers are performed by other contractors and their documentation is reviewed by the Marriott inspectors.

The inspection performed by Marriott is not limited to the required testing and inspections of the building systems. Through on-site training, the facility staff understands the importance of the systems within the buildings they operate. At the conclusion of the inspection, the associates should be familiar with the following:

- Where the sprinkler control valves are located and how to isolate a sprinkler zone. In case of sprinkler activation, this will reduce water damage and prevent closure of the main sprinkler supply valve.
- How building systems will operate when an alarm is activated. For example, will a guest room smoke detector send a signal to the fire alarm control panel?
- The importance of passive fire protection systems: smoke and heat can travel through openings in drywall, ceiling tiles out of place, fire doors propped open and laundry chute access doors that no longer close and latch.
- How to store items properly, including flammable liquids and gases and all other items that can be hazardous if not stored properly.
- What inspections are required and at what frequency. They are also instructed on how to conduct these inspections – for example, running the fire pump on a weekly basis and performing quarterly sprinkler waterflow and tamper testing. Marriott encourages staff to conduct these tests and inspections themselves rather than hire a company to do them; so they develop an in-depth familiarity with the systems and understand them in detail.

The above items would not be covered by contracting an annual fire alarm or sprinkler inspection with a vendor.

At the conclusion of the inspection, the Marriott inspector reviews any deficiencies found with the general manager and the building engineer of the hotel. A detailed inspection report is completed by the Marriott inspectors using a database that is interactive with the hotel management team. They are able to access the report as well as update action plans and deficiency correction dates. This feedback is monitored by Marriott to ensure that deficiencies are addressed and needed maintenance is performed.

Marriott is able to use the data gathered through the inspections to their advantage. They are able to identify problem areas in the hotels and what particular issues need more emphasis during the inspection or training. Marriott also uses the information to assist in the development of operating policies as well as design standards. For example, inspection results have indicated that fire alarm systems become difficult to maintain and keep in proper operating condition after 15 or 20 years in use. They work with the building owners to anticipate and plan for the cost of replacing and updating a fire alarm system. They also work with fire alarm manufacturers to promote improvements to their product lines.

CHALLENGES

Marriott has experienced some challenges in conducting its own inspections. One of those has been with local and state jurisdictions. Many jurisdictions have adopted regulations requiring various licenses or certifications for inspectors. The goal is to guarantee a certain level of competency among inspectors. However, Marriott has found through working with contractors that despite the licenses, the quality of inspector can vary greatly.

These regulations make it difficult for companies like Marriott to conduct inspections because it would be nearly impossible for them to hold individual licenses in a multitude of jurisdictions. In those areas, they work with a licensed or certified local company to assist in or conduct the inspection and to provide the necessary tags or certificates. This adds cost to Marriott hotels as well as to all buildings in those jurisdictions. Marriott would like to see jurisdictions focus on enforcing the adopted codes and standards rather than on licenses and permits that require companies to charge more for inspections and increase the administrative burden for the jurisdiction, the inspection companies, and the building owners and operators.

Another challenge Marriott faces is UL's Alarm System Certification. Where jurisdictions have adopted a regulation requiring alarm systems to hold a UL certificate, there is a large burden placed on the building owner. This certificate involves much more than simply using a fire alarm panel or equipment that bears the UL mark. The certificate is actually held by a fire alarm company – a company that certifies that the equipment is listed for the application; that the design and installation is in accordance with codes and standards; that trained alarm technicians installed the system; that a service contract is in place and that repair service is done by trained alarm technicians.

While the concept of these things is good, in reality the building owner is put in a difficult position. They are not able to negotiate services or prices because if they fail to comply with the demands of the alarm company, the company will cancel the UL certificate, which they are then required to report to the Authority Having Jurisdiction (AHJ). Although UL believes it is possible to have competition among companies, it is difficult to find a fire alarm company that is willing pick up a UL certificate from another company, because they then have to accept responsibility for the design and installation of a fire alarm system that they themselves did not design or install regardless of the fact that it was originally reviewed and accepted by the


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AHJ prior to occupancy of the building. Although the UL Certificate does provide some peace of mind for the AHJ, the cost to the building owner is excessive and unnecessary.

MOVING FORWARD

Marriott finds that owners are generally underrepresented in the code-making process. Owners and users of the code, including Marriott, should make an effort to become more involved and have more of a voice.

In addition, Marriott feels the AHJ plays a crucial role in ensuring that regular testing and inspections are performed. Marriott would like to see the AHJ in the building, participating in inspections rather than emphasizing local licensure of inspectors. Although this is a challenge for local officials, many do an excellent job and the building owners and occupants benefit from their participation. Marriott also encourages local and state officials to consider more deeply the impact to building owners and operators when drafting and adopting new regulations.

Marriott recognizes that it is not only the building owners' responsibility to maintain their buildings and fire protection systems, but it is also in their best interest. Hospitality extends beyond décor, cleanliness and excellent service. The guest must also feel safe and be protected. If all of the pieces are in place, customers will return again and again. The top tiers of management within Marriott International Inc. have a corporate commitment to life safety. This makes the Marriott inspection program possible.

Stacy Welch is with Marriott International Inc.

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Info: http://grupos.unican.es/GIDAI/

November 10, 2010
Fire Safety Engineering in the UK:
The State of the Art
Edinburgh, Scotland
Info: www.fireseat.org

December 7–9, 2010
8th Asia-Oceania Symposium on
Fire Science and Technology
Melbourne, Australia
Info: www.vu.edu.au/aosfst

December 16–17, 2010
SFPE Advanced Fire Alarm Systems Design
Orlando, FL, USA
Info: http://www.nfpa.org/catalog/product.asp?pid=ADFA&cookie%5Ftest=1

March 23–24, 2011
FSE '11 – Raising the Bar
Sydney, Australia
Info: www.sfs.au.com

May 25–27, 2011
Eurofire 2011
Paris, France
Info: www.eurofireconference.com

June 20–24, 2011
10th International Symposium on
Fire Safety Science (IAFSS10)
University of Maryland, USA
Info: www.iafss.org

October 23–28, 2011
The Annual Meeting:
Professional Development
Conference and Exposition
Portland, OR, USA
Info: www.sfpe.org

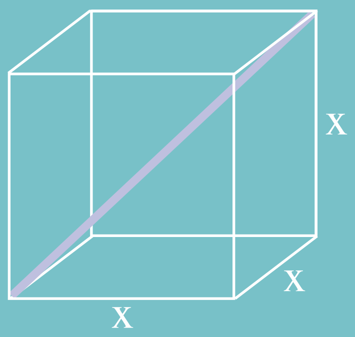
BRAINTEASER > Problem / Solution

Problem

You are on the bank of a river with a boat, a fox, a hen, and an ear of corn. You have to get the fox, the hen, and the corn to the other side of the river. If left alone, the fox will eat the hen; the hen will also eat the corn if left alone. The boat is only big enough to take you and one of the other three to the other side of the river. How do you get all three across intact?

Solution to Last Issue's Brainteaser

If a cube has sides with a length of X, what is the length of the interior diagonal of the cube?



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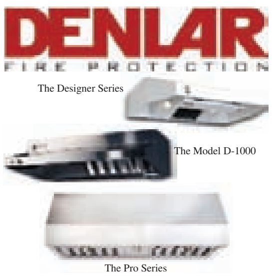
DENLAR FIRE PROTECTION

Case Study for Denlar Fire Protection – Fire Suppressive Range Hoods



Denlar Fire Protection is the industry's only manufacturer of a fully integrated Fire Suppressive Range Hood for institutional and residential use. Their units have been installed into various applications across the country and are widely accepted by local authorities. When regulators and safety conscious design engineers demand commercial-type fire protection over a residential-type range, the Denlar family of products is always a perfect fit.

Their systems are UL300A and UL507 listed, come fully charged and ready to install. Each unit is designed for ease and speed of install, carries a one year parts and factory labor warranty and offers numerous options and capabilities unique to the marketplace. They can also be configured for gas or electric and any ducting configuration. While there is an impressive amount of advanced technology that goes into their products, each model features an independent mechanical suppression system based on standard fail-safe components.

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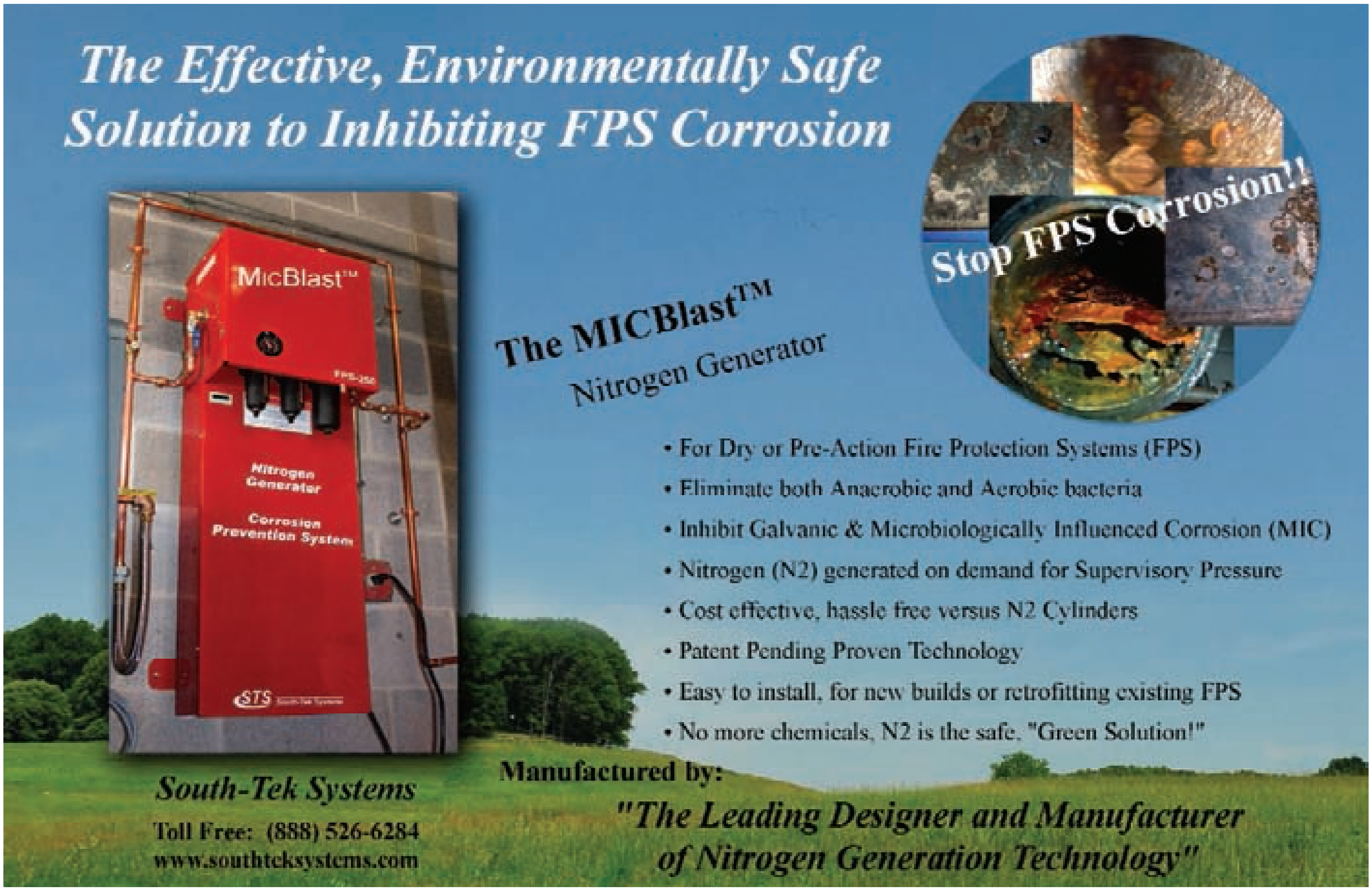

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—Gamewell-FCI

Online Tools for AV Design

System Sensor provides online tools to aid the design process of an audible/visible (AV) system. To assist with several necessary upfront tasks and calculations that can be tedious and complicated, System Sensor provides an online Voltage Drop Calculator, a Mounting Options Tool and an Equivalent Facilitation Calculator, all found at *www.systemsensor.com/tools*.

www.systemsensor.com/tools

—System Sensor

Simulation Tools for Performance-Based Design

Thunderhead Engineering offers PyroSim and Pathfinder to assist with the performance-based design process. PyroSim helps you build model input for FDS, with features such as 2D/3D CAD import and FDS and Smokeview integration. Pathfinder is a validated, agent-based, evacuation simulator that can run stand alone, or be integrated easily with existing 2D/3D DXF files, FDS, and PyroSim geometry. Free 30-day trial downloads are available for both applications.

www.thunderheadeng.com

—Thunderhead Engineering

Helmet Lighting Kit

Streamlight's new PolyTac® Helmet Lighting Kit features a PolyTac® LED flashlight and a Blackjack Helmet Mount by 1445 Designs. The universal kit is a low-profile, lightweight, and economic alternative for securely mounting the PolyTac LED flashlight to almost any style helmet, traditional or modern. The lithium-powered light weighs only 3.9 oz., features a body made of high-impact, super tough nylon polymer, and includes a C4® power LED to deliver 120 lumens.

www.streamlight.com

—Streamlight

Sealed Plastic Ignition Switches

These fully-sealed plastic ignition switches are constructed of durable, engineering-grade plastic and are available in a variety of configurations to meet all customers' needs, including anti-restart. The switches have an integral Deutsch connector, and the contacts are sealed to IP-67. Available with or without a key boot, the switches are rated at 10A at 12V DC, 5A at 24V DC, and are tested to SAE J259 for ignition switches.

www.colehersee.com

—Cole Hersee Co.

Protect Critical Installations with Engineered FM-200 Fire Extinguishing Systems

Janus Fire Systems is a U.S.-based manufacturer of Underwriters Laboratories Listed and Factory Mutual Approved special hazard fire systems. FM-200® clean agent extinguishing systems protect critical installations such as computer rooms, server farms, switch gear rooms, telecommunications centers, archival storage facilities and other high value assets. FM-200® is a clean, colorless, and environmentally friendly fire suppression agent that is electrically non-conductive and safe for humans. Extinguishing flames primarily through heat absorption and leaving no residue, making FM-200 suppression systems accepted and respected worldwide. Janus Fire Systems is your gateway to a new kind of service.

www.janusfiresystems.com

—Janus Fire Systems


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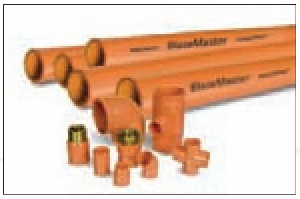
Quick Release Fire Extinguisher Mount

The Quick Release Fire Extinguisher Mount can be secured to any flat or round surface using either bolts or hose clamps. Configurable for any size fire extinguisher, this mount offers split-second removal to maximize emergency preparedness. Poly Performance manufactures the two-piece mounting system from laser-cut 3/16-inch and 1/8-inch-thick high-strength steel. Zinc plating provides corrosion resistance and a finished look. Right Hand and Left Hand Release Pins are available.

www.polyperformance.com

—Poly Performance

Nonmetallic Fire Sprinkler System



Corrosion-resistant BlazeMaster® nonmetallic fire sprinkler systems feature pipe that can be cut on-site with simple hand tools. BlazeMaster systems have a Hazen Williams "C" factor of 150 and are designed to a 50-year life expectancy with a safety factor of two. The system is Listed by Underwriters Laboratories, Underwriters Laboratories of Canada, and the Loss Prevention Council and are Factory Mutual (FM) approved for light hazard and residential occupancies.

www.blazemaster.com

—Lubrizol Corp.

Thermo-Activated Shut-Off Device

FireBag® thermo activated shut-off devices shut off gas supply when ambient temperatures reach 212°F. When the outside temperature reaches 203-212°F, the metal alloy in the FireBag that keeps plug and cartridge together melts and the spring pressure pushes the plug against the gas opening to close it completely. Once triggered, the shut-off device works up to 1,697°F for one hour. No fire or heat detectors are required to automatically intercept gas flow.

www.assuredautomation.com

—Assured Automation

AIR-Intelligence Aspirated Air Sampling Smoke Detection System Introduced by AirSense® Technology

AIR-Intelligence™ products provide superior early warning smoke detection that adapts to virtually any environment and the normal fluctuations within those environments. The AIR-Intelligence ASD-160H, ASD-320 and ASD-640 detectors have unmatched sensitivity potential, providing the very earliest warning of incipient fire with minimal nuisance alarms for applications ranging from computer cabinets and museums to aircraft hangars and airport terminals..

www.air-intelligence.com

—UTC Fire & Security

Redesigned Indoor/Outdoor Siren

Potter has introduced the new Amseco SSX-52 Series Indoor/Outdoor Siren to replace the existing SSX-51 Series. The SSX-52 Series offers a new look and design to improve overall performance and aesthetics of the installation. A polycarbonate housing is attached to a sturdy aluminum back plate. The aluminum back plate offers greater protection against vandal attacks and does not warp or crack during installation. An optional strobe is available in amber, red, clear, and blue.

www.pottersignal.com

—Potter Electric Signal Co., LLC

Visual Flame Detector

The Micropack FDS-301 Visual Flame Detector is designed to detect flames in high hazard applications and automatically provide a live video image of the area being protected for situational analysis. Due to the sophisticated algorithms onboard the detector, common nuisance alarm sources that affect conventional flame detectors are ignored. Once an event has been detected the video file is automatically written and stored to a micro SD card, to aid in fire forensics.

www.micropackamericas.com

—Micropack Detection (Americas) Inc.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MID-ATLANTIC
BILL BOYADJIS
District Manager
P.O. Box 762
Morris Plains, NJ 07950
973.829.0648
fax 913.514.6380
bill.boyadjis@penton.com

NEW ENGLAND/ NORTH CENTRAL/ SOUTHEAST
JOE DAHLHEIMER
District Manager
745 Damon Drive
Medina, OH 44256
330.289.0269
fax 913.514.6481
joe.dahlheimer@penton.com

CENTRAL/WEST
JOHN EHLEN
District Manager
17340 46th Ave. N.
Plymouth, MN 55446
763.550.2971
fax 763.550.2977
john.ehlen@penton.com

CALIFORNIA/TEXAS
RANDY JETER
District Manager
908 Electra
Austin, TX 78734
512.263.7280
fax 913.514.6628
randle.jeter@penton.com

INSIDE SALES
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david.kenney@penton.com

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Fire Protection Engineering (ISSN 1524-900X) is published quarterly by the Society of Fire Protection Engineers (SFPE). The mission of *Fire Protection Engineering* is to advance the practice of fire protection engineering and to raise its visibility by providing information to fire protection engineers and allied professionals. The opinions and positions stated are the authors' and do not necessarily reflect those of SFPE.

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Cleveland, OH 44114-1503
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BILL BOYADJIS
District Manager
P.O. Box 762
Morris Plains, NJ 07950
973.829.0648
fax 913.514.6380
bill.boyadjis@penton.com

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JOE DAHLHEIMER
District Manager
745 Damon Drive
Medina, OH 44256
330.289.0269
fax 913.514.6481
joe.dahlheimer@penton.com

CENTRAL/WEST
JOHN EHLEN
District Manager
17340 46th Ave. N.
Plymouth, MN 55446
763.550.2971
fax 763.550.2977
john.ehlen@penton.com

CALIFORNIA/TEXAS
RANDY JETER
District Manager
908 Electra
Austin, TX 78734
512.263.7280
fax 913.514.6628
randle.jeter@penton.com

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