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What's Inside…

Procedural Aspects of: Lockout/Tagout, confined Space Entry and Warnings

by Gary M. Hutter, Ph.D., P.E., C.S.P.

Abstract

OSHA's requirements for Confined Space Entry and for Lockout/ Tagout have some similar procedural requirements for safety. Because these standards rely heavily on procedures which address actions of humans, they are often subject to interpretations and a decision or judgment process. The most critical issues obviously are when the requirements of the standards apply, but other issues include the use of warning signs, postings, and application. OSHA has issued interpretations on some of these items, others seem to be based on custom and practice in the field.

Anatomy of a Failure

by Mitchell P. Kaplan, P.E., DER

Abstract

A structure or component may fail for many reasons. Five of them are, imperfections within the material, inappropriate design, usage, i.e. stresses, beyond that assumed, a deleterious environment or its' useful life have been exceeded. The analyst, trying to determine the underlying mechanism must be cognizant of all these. He embarks upon an investigation to determine the root cause. This paper describes that investigation.

Fuel Gas Incident Fire/Explosion Investigation – Good Practices and Guidelines

by KIm Mniszewski, P.E.

Abstract

A fire/explosion incident involving a fuel gas can present unique challenges for investigators. The investigation methodology presented in NFPA 921 should be followed. Several good practices and guidelines are presented to ensure that the most useful information is gathered from the scene, as it will set the stage for good reconstruction efforts.

Developing a Guardrail Test Criteria

by William G. Switalski, P.E.

Abstract

Recently, the members of the American National Standard committee for Mobile Ladder Stands and Ladder Stand Platforms, ANSI A14.7, were faced with the task of developing a test criteria for the guardrail system for this class of products. The guardrail system did not have strength or performance requirements in earlier revisions of the A14.7 safety standard. In an effort to provide the code committee with a basis from which to develope a guardrail testing criteria, the author researched the guardrail strength criteria in other standards for products and structures containing guardrail systems. There were two approaches discovered for addressing guardrail appropriateness; construction features and strength testing. This article summarizes the results of the research that was presented to the members of the A14.7 committee.

Procedural Aspects of: Lockout/Tagout, Confined Space Entry and Warnings

by
Gary M. Hutter, P.E., Ph.D., C.S.P.

I) Introduction:

Methods of "**Safeguarding**" equipment can often be divided between physical safeguarding devices, and procedural methods. A barrier guard, a fuse, an interlock, a light curtain are all examples of "*physical*" methods of safeguarding. Under "*physical safeguarding*" there typically is some device that provides the primary component of safety. Training, operating procedures, safety admonitions, permits, operating licenses and all examples of procedural methods of safeguarding. Following the "*procedures*" provides the primary component of safety. These two categories of safeguarding are analogous to the hardware and software approaches to safety, and may be companions of overall safety.

The procedural, or software-like aspects of safeguarding play important roles in assuring safe workplaces, and have been well utilized in both of OSHA's **Lockout/ Tagout** requirements (29CFR1910.147), and in their **Permit Required Confined Spaces** entry requirements (29CFR1910.146) Under Permit Required Confined Space entry, many of the requirements of the Lockout/ Tagout criteria may apply. A review of OSHA's "Interpretations" reveals the interplay that may exist between these two standards for such things as equipment/ electric power isolation. Without following the proper procedures of these two standards individually or in combination, compliance will most likely fall short, and accidents are more likely to occur.

With "hardware" safeguarding there is less left to interpretation and decision making; whereas with procedural safeguarding, interpretation and decision-making play more predominant roles.

The following article briefly discusses a few of the interpretation and decision-making activities associated with OSHA'S Lockout/ Tagout and the Permit Required Confined Space criteria in reference to "warnings/ signage posting." Both standards address warnings/ signage posting in their text.

II) Brief Description of Lockout/ Tagout Practice and Warnings

> ***"Lockout/tagout"*** *refers to specific practices and procedures to safeguard employees from the unexpected energization or startup of machinery and equipment, or the release of hazardous energy during service or maintenance activities. This requires, in part, that a designated individual turns off and disconnects the machinery or equipment from its energy source(s) before performing service or maintenance and that the authorized employee(s) either lock or tag the energy-isolating device(s) to- prevent the release of hazardous energy and take steps to verify that the energy has been isolated effectively."*
> (http://www.osha.gov/SLTC/controlhazardousenergy/recognition.html, OSHA Web site 11/04)
>
> *"Tagout device: A prominent warning device, such as a tag and a means of attachment, which can be securely fastened to an energy isolating device."* 29CFR1910.146(b)def
>
> *"Durability... tagout devices shall be capable of withstanding the environment to which they are exposed ..."* 29CFR1910.147(c)(5)(ii)(A)
>
> *"Tagout devices shall warn of hazardous conditions..."* 29CFR1910.147(c)(5)(D)(iii)

III) Brief Description of Permit Required Confined Space and Warnings

" Permit Required Confined Spaces" *Many workplaces contain spaces that are considered "confined" because their configurations hinder the activities of any employees who must enter, work in, and exit them. For example, employees who work in process vessels generally must squeeze in and out through narrow openings and perform their tasks while cramped or contorted. OSHA uses the term "confined space" to describe such spaces. In addition, there are many instances where employees who work in confined spaces face increased risk of exposure to serious hazards. In some cases, confinement itself poses entrapment hazards. In other cases, confined space work keeps employees closer to hazards, such as asphyxiating atmospheres or the moving parts of machinery. OSHA uses the term "permit-required confined space" (permit space) to describe those spaces that both meet the definition of "confined space" and pose health or safety hazards."*
(http://www.osha.gov/SLTC/confinedspaces/index.html, OSAHA Web site11/04)

"If the workplace contains permit spaces, the employer shall inform exposed employees by posting danger signs or by other equally effective means, of the existence and location of, and the danger posed by the permit spaces." 29CFR1910.146 (c)(2)

"The completed permit shall be made available to all authorized entrants by posting it at the entry portal or by any other equally effective means..." 29CFR1910.146 (e)(3)

IV) Discussion based on OSHA Interpretations

The Safety Hierarchy[1] approach to safety has "warnings" as a lower level item, than physical safeguards. The OSHA standards for the Control of Hazardous Energy (Lockout/ Tagout) and Permit Required Confined Spaces, both rely heavily of procedural methods, including warning and warning-like written items. A review of the OSHA web sight indicates several dozen requests for interpretations of various aspects of these two standards. Both standards require posting of signage ("posting" as a confined space/ "tagging" as locked out) under certain conditions; but the details of this posting is subject to some vagary, and is one issue explored in the interpretations of OSHA.

A) Custom & Practice and Tagout

There are many situations where a mechanic is working on a vehicle with the engine running and an accompanying hazard may be present; would that mechanic need to lockout and tagout the equipment? In a May 20, 1991 OSHA interpretation[2] (P.K Clark, Directorate of Compliance Program to Mr. Raymond Halsdey, Colin Laboratories), certain adjustment maintenance on a truck with its engine running is considered to fall under the lockout/ tagout criteria. A strict interpretation of the requirements of that standard would suggest that the vehicle be "tagged out." Based on a cursory review of vehicle maintenance shops, it is not customary practice for vehicle mechanics to post lockout and tagout signage on vehicles.

Furnaces are sources of carbon monoxide (CO). To find a leak of CO it is important to have the furnace operating, as the exhaust flow, thermal cycling, and formation of the CO gas are all critical in the evaluation. It is impractical; to tagout many furnaces when checking for small leaks of CO gas, and technicians commonly run such tests with the furnace operating..

Tagging out following OSHA guidelines is not always performed and is not always possible for all maintenance tasks, and for some operations the custom and practice is in conflict with the tagout notion (See Figure 1).

B) Alternative Methods/ Considerations

Do all confined spaces need to have a posting at all times that they are confined spaces? Every manhole found in a street can be expected to lead to a confined space, most of which are likely to be Permit Required Confined Spaces (PRCS). It would be most rare to see such manholes posted as confined spaces. In an OSHA Interpretation dated March 13, 1998 from J. Miles, Directorate of Compliance Program, to Mr. J. Mc Damiel it is stated that "signs would be the principal

Figure 1

method of warning under the standard." But that there are alternative methods."[3] These "alternatives" include training and other communications.

Similarly, the telecommunications industry has one of the largest collection of confined spaces and subterranean vaults. This industry is not bound by the labeling criteria suggested in 29CFR1910.146 and an inspection of many telecommunications facilities shows that PRCS labeling is not the most common means of addressing this problem, but training is the common mode of safeguarding.

C) Appearance of Postings/ Signage

There are several American National Standards Institute (ANSI) standards that address the design and configuration of tags and signs (e.g. ANSI Z353 Series). OSHA can adopt this criteria under their General Duty clause 5(a), where there is no existing OSHA standard for a tag or signage. In the August 30, 2002 OSHA Interpretation from Mr. Richard Fairfax, Directorate of Enforcement Programs, to Mr. Mr. R. Austin, there is a discussion of the appearance and form of a lockout tag. In that communication there is a rather bland tag offered for review as to its adequacy (See Figure 2). The OSHA representative could not specifically accept or reject the tag, indicating other considerations were needed to make the decision. In essence, lockout tags should be:

> *"standardized within the fcaility tin at least one of the following crteria: color, shape, or size ..."*

1 The Safety Hierarchy is one means of prioritizing safety based on general notions in the safety literature.

2 "If a truck driver ... were to crawl under a truck, wi h the engine running, to adjust a linkage or fix another problem, would this be considered a violation of the standard? The answer is yes ..."

3 "If a space has a locked entry cover or panel, or an access door that can only be opened with special tools, the use of sign's may be unnecessary." Standard Interpretations 07/22/1998 - Requirements for posting signs for PRCSs. 1910.146(c)(2)

DANGER This lock belongs to:

EQUIPMENT LOCKED OUT NAME: ____________
DEPT: ____________

Question: Do labels, which are usually white in background meet the requirement for the locks to be unique by size, shape or color?

Reply: Color is not the only prescribed factor for the standardization of lockout and tagout (LOTO) devices. At a minimum, a lock's shape, or size or color must provide employees with the capability to identify and distinguish a lockout device from other similar devices (e.g., security locks) in the workplace.

Figure 2

V) Conclusions–/Closure

Procedures and practices are becoming more important in improving safety standards. Some safety procedures and practices rely more on people, and less on devices; are more difficult to codify because of local conditions; and are more subject to interpretation and discussion.

OSHA does offer written guidance on many of these items through their “Interpretations” available in the public domain. Consultation of these materials helps to define the problems and concerns for implementation of such codes and standards.

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Anatomy of a Failure

by

Mitchell P. Kaplan, P.E., DER

Introduction

This article is not going to discuss, in depth, any particular failure. Rather, it will describe the mechanism of determination of the root cause of a failure. The type of failure discussed will be that of a material, i.e., the failure will be separation of one piece of material (metal, composite, plastic, glass, wood) into two or more parts. Failure analysis is used as the how and why that this material failed. It is assumed that the failure of this material rendered the component unusable. The failure may have significant safety issues attached to it, or the component may have been designed to be fail-safe. Fail-safe is a design concept that says that the failure of a primary component is acceptable for a limited time. That limited time depends upon the observation of the failure. If the failure is extremely obvious, then the time can be quite short. If the failure can be found only through a periodic inspection, the time must be at least two inspection intervals.

Prior to one discussing failure, one must discuss a particular design. Generally speaking. One perceives a particular product, its end use, its general appearance, the market, the cost, the complexity of manufacture, the product life, the life of the product and product safety before designing it. There are other parameters that are examined before as well. However, the discussion here is not to talk about product design, but rather product failure.

After a product is designed and manufactured, it used in the marketplace. We all try to manufacture products that will not fail, but to no avail. Products fail! Sometimes they fail because of the design process, sometimes the manufacturing process and sometimes how the product is used. In addition, the product may have outlived its usefulness. Products generally have a finite life. If they are used beyond this life, failure occurs. The purpose of the failure analysis is to determine which of these four failure modes were operative in a particular event.

Engineering Requirements

When a product is conceived, there are usually many different inputs to determine its final design and introduction to the marketplace. These include, but are not limited to marketing, sales, finance, manufacturing, distribution and engineering. Obviously, if there is not a need and if the product cannot be made efficiently enough to guarantee a positive return on investment, it will not be made.

Engineering has a large role in this decision. Engineers need to design the product so it can be manufactured, manufactured efficiently, manufactured safely, be durable, be easy to use and be used safely. It also is necessary that the product worked appropriately and had a failure rate that was significantly small. These constraints are those that add to the complexity of engineering design and manufacture.

The engineering disciplines that are required for design of a particular component are defined by the component itself. In many instances, materials engineers are part of this process. The materials engineer works in conjunction with the other engineering disciplines to define the final product. If we choose a product such as a ladder or scaffold, the engineering disciplines can be straightforwardly determined.

These would include mechanical designers, materials engineers, mechanical engineers, manufacturing engineers and quality control. Each of these groups has its own particular niche and again they must be part of the whole.

What needs to be defined is the particular task for which this ladder or scaffold would be used. If we assume it is a ladder, is it to be a stepladder, an extension ladder, a combination ladder or a painter's ladder. Is to be manufactured from wood, metal or composite? These constraints may be given to engineering by marketing or sales. The selling price may be defined as well.

After some of these decisions are made, the durability of the ladder must be defined as well as the "Type" of ladder. Type in this instance refers to the magnitude of the load the ladder is designed to hold. Then engineering design, saddled with these constraints, enters the picture.

Given the type, given the length, given the design constraint (stepladder, extension ladder, etc.), decisions regarding the external environment must be defined as well as it anticipated usage. From these parameters materials and manufacturing methods can be defined. The materials engineer must work in conjunction with the design engineer, the mechanical engineer and the manufacturing engineer.

A result of this process defines the materials, the geometry of the material, the attachment of the materials and subsequently the design itself. Standards must be evaluated to ensure that the final product meets or exceeds all standards.

Only then can the ladder be manufactured. Again, other disciplines become increasingly important. These include, in addition to the others, manufacturing and quality control. This is from the product manufacturing perspective. There are others, external to the manufacturing processes that are intimately involved.

Field Failure

Let us assume that a ladder has been manufactured. Let us further assume that it was involved in an accident. The materials engineer will become involved if some portion of the ladder failed or was deformed. The investigation would examine many parameters and examine many aspects of the accident.

What is critically important is to examine the ladder itself and the site where the accident took place. At both these examinations, photographs would be taken to preserve the particular geometries and 'freeze' the condition of both the ladder and the site. In addition, measurements of the ladder and the site, along with drawings (to scale), would be prepared.

The next item would be to try to reconstruct the accident. The goal is to determine if the failure or the deformation preceded the accident or was a result of the accident. Implicit in this is an investigation of the ladder itself and its capability to perform its intended task. That investigation would include the geometry of the ladder, the materials from which the ladder was manufactured, the manufacturing quality of the ladder, whether the ladder met the specifications from which it was designed.

As a ladder is used for climbing, the loads that would be placed upon the ladder, their frequency and the type of abuse to which the ladder would be exposed is information that needs to be defined.

If there is a failure of a component, the cause of the failure must be determined. Were there rivets that had failed, what kind of failure? Was it a bearing failure, a fastener failure, was the rivet properly bucked? Was there a component failure? If so, what caused the component to fail? Was it fatigue, corrosion, overload? Were the materials of adequate strength?

A metallurgical examination may be necessary to ascertain the particular reality. A metallurgical examination is destructive in nature. It generally consists of four discrete parts. These are:

- OPTICAL EXAMINATION: This is usually done with a binocular microscope. The magnification level is relatively low, up to about 35X. From this examination, one can usually tell the mode of failure. Figure 1 below shows an example of a fatigue failure. Fatigue striations are visible in the upper half of the figure, while overload (fast failure) is visible in the lower half of the figure.

- A HARDNESS TEST: This is used to determine the strength of the material. The test itself in nondestructive in nature. However to perform the test a flat piece of metal is needed. To obtain this, it is usually necessary to separate a piece of material from the component.

- A METALLOGRAPHIC EXAMINATION: This is used to examine the grain structure of the material. Processing of the metal including its grain structure. Cleanliness can be defined. Failure mode may also be determined. A small section of the material is removed and placed into a plastic mold. The metal is polished and etched to bring out the substructure. It is then examined in an optical microscope.

- A SCANNING ELECTRON MICROSCOPY EXAMINATION: This is used to determine the failure mode. From this examination, one can generally determine

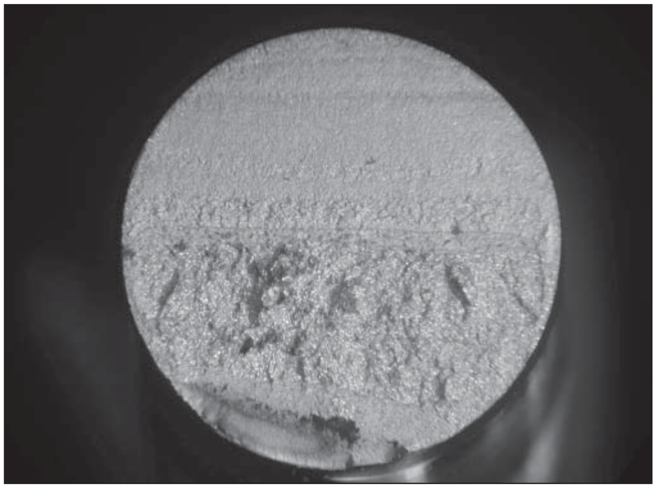

Figure 1. Macroscopic Photograph

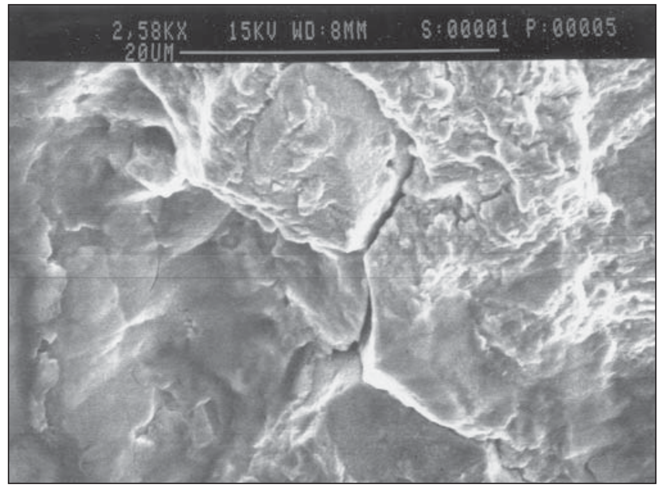

Figure 2. SEM Photograph

the failure mode. A small piece of metal, containing the fracture, is placed into the chamber of the SEM. High magnification with good depth of field allows the analyst to determine, in many cases the root cause of the failure. One can determine whether the failure was due to fatigue, corrosion, overload failure and whether the material was ductile or brittle. Figure 2 shows that the fatigue failure was initiated by intergranular failure, a particularly brittle and unwanted condition. In this photograph one may see the individual grains with cracks surrounding them.

It is useful and often necessary for the analyst to understand the loading on the particular component. Given this information, along with the geometry of the part and the material from which it was constructed, a stress analysis may be performed. Coupled with the metallurgical examination generally allows one to determine the root cause of failure. From this, one may ascertain if the failure was the causation or was a result of the particular incident.

Conclusion

One may see that the determination of a failure is not a simple task. There are many disciplines that are required and much information must be obtained. This article discusses, in more detail, the utility of a metallurgical examination. Other analyses and test may also be required. Future papers will discuss these in greater detail. It may be seen that the engineer, as an independent analyst, is tasked with finding the cause of the incident. This introduction gives some insight into this method.

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Fuel Gas Incident Fire/Explosion Investigation – Good Practices and Guidelines

by

KIm Mniszewski, P.E.

After a fire/explosion incident, it is sometimes obvious that a fuel gas (i.e. natural gas, propane) was involved. For example, when natural gas is found to be the only diffuse fuel available in the facility, and the explosion effects are consistent with that of a natural gas event, and the gas system is found leaking post-explosion, chances are that natural gas was involved. This is often the case for residential home explosions. Sometimes it's not so obvious and it can be wrongly assumed.

After it is established that fuel gas was involved, the investigation can then focus on determining the events that occurred that resulted in the unwanted release of flammable gas.

Whether you are representing the facility owner, the gas supplier company, an injured party, or other party, it is important to ensure that a proper investigation is undertaken to best uncover the truth. A proper fire investigation will adhere to the principles of NFPA 921. Each investigation is unique, requiring the use of good judgment and common sense. Some good practices and useful guidelines for a scene investigation involving a fuel gas incident are as follows:

- Strive for an investigation as soon as possible. If too much time lapses before an investigation begins, gas system component items may be disturbed/changed by weather conditions (i.e. causing corrosion, etc.) and/or any -

unwanted tampering with the scene. These changes will make it more difficult to analyze the scene.

- Always prepare a plan view diagram of the structure, showing the location of all gas-related appliances, as well as all gas piping, regulators, meters and tanks. On the same diagram or companion diagrams, it is useful to show areas indicating the intensity of burning, any directional fire spread and any directional effects of an explosion. It may be useful to include an additional diagram showing the location of photographs taken.

- Make sure that plenty of photographs are taken of the scene. It is common for an investigator to find that he should have of taken a few more photos of a certain area. Photographs are relatively cheap and can be a primary tool for use in any litigation involved. A photographic log should always be prepared and detailed so that there is no question about what was documented.

- Where gas appliances may be involved, the details of each relevant appliance should be documented. This should include the make, model number, serial number and date code. If there are separate control components (i.e. regulators, control valves, etc.), those should be documented similarly.

- Where there is evidence of an explosion, document any relevant blast indicators of interest so that a subsequent analysis will be easier for any engineers involved. For weak explosions, this should include any windows broken from the explosion (as opposed to a fire where soot staining may have occurred), including pane fragment size, type and thickness. Such glass fragment distances should be measured. Any directional structural displacements and heat patterns should be noted, measured and photographed, e.g. a wall that is partially moved. Directional heat/burn patterns may also be resident on injured victims. For more intense explosions, any major structural displacements should also be noted, measured and photographed, e.g. a wall/roof that has blown away, the shattering of structural members, etc.

- Where an odorized fuel gas such as propane or natural gas is involved, check for gas odor at the gas source, if possible. At a minimum this should be done at the site by sniff test, and if public sector officials are present (fire marshal or fire department staff) they should be asked to sniff the gas too. If this is done, notes should be made as to who participated. Where serious injuries or death is involved, a proper gas sample should be taken and analyzed by a reputable laboratory for the quantitative level of odorization.

- Where underground gas migration is a factor, it will be necessary to establish migration pathways. Soil types and underground features should be documented. In some cases, bar hole survey sampling or a related technique will be necessary to establish the migration pathway and source of gas. When no underground gas piping is found to be related to the source, gas sampling and laboratory analysis should be conducted to determine if the fugitive gas is from natural organic decay or other.

- Depending on the fuel gas source, any information regarding usage should be gathered, as it may prove useful during any later analysis. For natural gas systems, this may include the current gas meter reading. Earlier readings can be obtained from billing records. For propane systems, the level of propane in the bulk tank or weight should be recorded. Earlier usage data can be obtained from billing records.

- The names of the witnesses to the fire/explosion should be gathered. If possible, interviews should be conducted and documented properly. Depending on your assignment, this may be impossible, and you may have to rely on the interview of public entities or others. It is important that all parties involved have access to key interviews during the fire investigation process. For incidents where injuries or deaths have occurred, it may be advisable to have an attorney present for the interviews.

- Local fire/police officials should be interviewed to gather facts from their observations and analysis, and also to provide information to them that may be useful in their investigation. Many times they are not interested beyond determining whether the cause is that of criminal or not. They also may not be aware of the technicalities involving fuel gas systems. As any report they create may be held in high regard, it is very important that they have all the information they need prior to writing it.

- Testing of suspect leaking piping or appliances should be conducted in situ when practical. As debris is removed, critical items may undergo additional stresses and be damaged. This will make it more difficult to sort out damage from the explosion/fire event and the original conditions. Where extreme damage has occurred to piping systems, it may be best to harvest all relevant portions of the piping system for later reconstruction and testing in a laboratory. Any testing of gas utility piping must be done in conjunction with the gas supplier.

- Collect relevant evidence and avoid spoliation. Piping system components and appliances in the area of any leakage should be preserved, and documented per the procedures of NFPA 921. No destructive testing of any item should be undertaken until the proper time when all parties involved have agreed upon how it's to be done. It may be useful to have an attorney involved to handle possible spoliation issues when such situations present themselves.

- Viable ignition sources from the area where the flammable mixture originated and/or accumulated should be collected as evidence using good judgment. However, where natural gas or propane is involved, nearly any ordinary electrical item may be suspect, given that the ignition energies for fuel-gases are so low. Then in many cases it becomes less important to establish the ignition source since there may be a multitude of viable sources.

- Any gas supplier company involved should be asked to preserve all relevant company records that may be needed for litigation. This should include the entire customer file, showing any deliveries or usage of gas, any complaints, and any service work. This should also include any records of odorization where possible. Propane suppliers should preserve any inventory and bill of ladings showing the bulk supply of gas for the last six months before the incident.

- When serious injuries or death are involved, a professional gas engineer should be consulted to inspect the scene and assist. In some cases, a structural engineer will be necessary as well to assist in understanding any structural weakness involved, the mode of structural failure, and estimating any explosion blast loads necessary to result in the observed damage.

After the scene investigation is complete, follow-up visits to the scene may be required in some cases to gather more detailed information. A subsequent laboratory examination and testing of components may be necessary in many cases. Some examples of lab procedures are: to quantify the leak rate of a leaking pipe fitting, to examine fractured pipe fittings under high magnification, or to establish the operating characteristics of a regulator, each of which is not easily done in the field. In some cases, it is useful to x-ray specific components (e.g. appliance gas control valve) before they are destructively disassembled, to preserve a record of their internal subcomponents and their orientation.

To determine whether particular hypothesized gas leak scenarios are probable, it may be necessary to have a gas engineer analyze the data gathered to determine whether a flammable gas concentration could have developed in the volume of interest and under the ventilation and infiltration conditions present. This can be done through gas concentration modeling calculations of the scenario, or more detailed computerized tools such as computational fluid dynamics. There have been many cases in litigation where one expert develops a "half-baked" theory of gas leakage accumulation, only to be dismissed later by another expert's compelling analysis showing that it physically can't happen.

Investigation photos of a small wood frame home after a natural gas explosion/fire are shown in figures 1 through 3. The remains of the home show that a powerful though low energy explosion had occurred throughout the entire volume, resulting in the heaving blow-down of all the walls and roof at the front of the home. An apparent suicide attempt was hypothesized as the flexible connector to the kitchen range was found to be disconnected to gas piping. A further examination of the connection threads in a lab confirmed that the connection was not forced off. Calculations showed that the gas flow rate from that open connection would be sufficient to fill the home with a sufficient flammable concentration to cause the damage within the timeframe involved. The injured party did eventually confess to removing the connection.

Figure 1 – Wood Frame Home Remains after Natural Gas Explosion

Figure 2 – Kitchen Range Involved in Home Explosion, as Examined in Laboratory

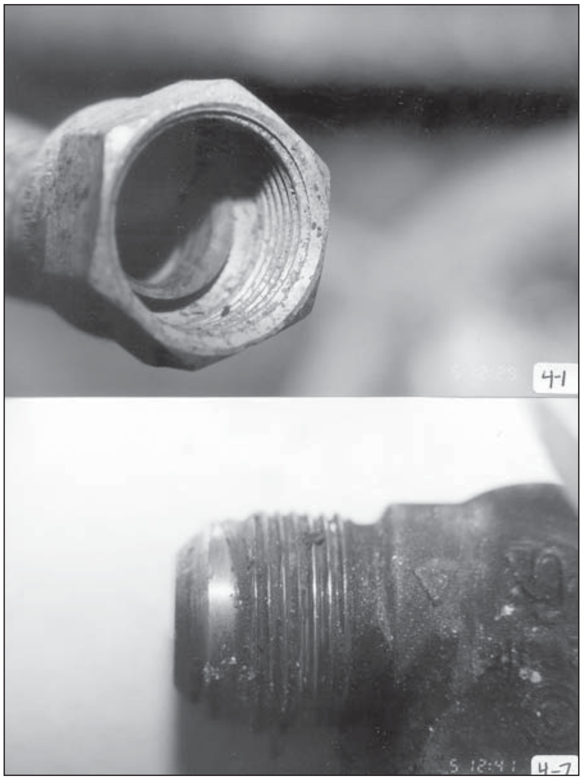

Figure 3 - Kitchen Range Flexible Connector Mating Fittings as Found after Explosion Even

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Developing a Guardrail Test Criteria

by

William G. Switalski, P.E.

As a committee member of the *American National Standard for Mobile Ladder Stands and Mobile Ladder Stand Platforms*, ANSI A14.7, the author and his colleagues are currently faced with developing a Guardrail/Handrail test criteria for a product which does not currently have a criteria established for railing strength. Figures 1 and 2 illustrate typical examples of the class of products covered by ANSI A14.7.

There are numerous sources of Guardrail/Handrail requirements that are already established in building codes and various other American National Standards addressing products that incorporate railings into their design. Clearly, this is an excellent starting point for researching railing strength criteria. This article will summarize these sources of information and provide guidance to the committee members involved in writing the next revision of the Mobile Ladder Stands safety standard.

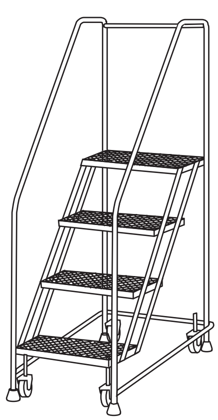

Fig. 1: Mobile Ladder Stand

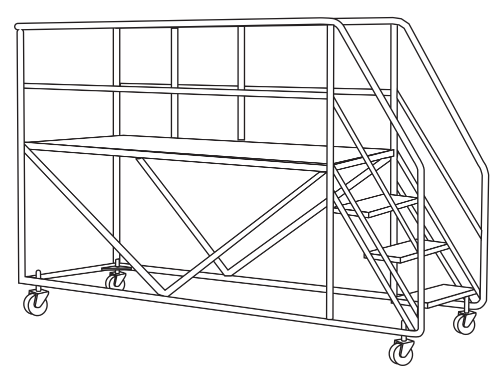

Fig. 2: Mobile Ladder Stand Platform

First, it is necessary to define terms such as “Guardrail,” “Top Rail,” “Mid-rail” and “Handrail” in the context which they will be used by the A14.7 committee. Since Guardrail will be used to describe several structural elements and features, the term, “Guardrail System” is more appropriate:

Guardrail System – The structure placed along the exposed sides and ends of the top step or platform of a ladder stand or a ladder stand platform providing a barrier from falls to lower levels. The Guardrail System consists of a top rail and mid-rail and may contain a toeboard.

Top Rail – The uppermost horizontal member of a Guardrail System.

Mid-rail – A rail approximately midway between the Top Rail and platform of a Guardrail System secured to the uprights erected along the exposed sides of the top step or platform.

Handrail – A rail connected to a ladder stand running approximately parallel to the step slope, top step or both.

Typical Building Code Requirements

The Uniform Building Code (1991) specifies that Balcony Railings and Guardrails for exit facilities in buildings serving an occupant load of 50 or more people to sustain a distributed load of 50 pounds per linear foot applied horizontally to the Top Rail. For any other application of Balcony Railings and Guardrails, a distributed load of 20 pounds per linear foot must be sustained. No Mid-rail requirements are given.

Handrails on stairways are required to sustain a concentrated load of at least 200 pounds applied in any direction at any point on the rail. Temporary railings provided for pedestrian protection are required to be “substantially built.” Although no specific railing strength is given, the Uniform Building Code describes an acceptable wooden railing constructed of new lumber with nominal dimensions of at least 2 inches by 4 inches. A Mid-rail is required when the pedestrian walkway is adjacent to an excavation.

The BOCA Basic/National Building Code (1984) requires that Handrails sustain simultaneous vertical and horizontal distributed loads of 50 pounds per linear foot applied at the Top Rail. For special applications including reviewing stands, grandstands, bleachers and similar structures, the requirement is increased to a vertical distributed load of 100 pounds per linear foot and a horizontal distributed load of 50 pounds per linear foot. (Note that BOCA recognizes the term Handrail or Railing, but not Guardrail.)

Scaffold Guardrail Requirements

The American National Standard for Scaffolding Safety Requirements, ANSI A10.8 (1988), does not prescribe Guardrail load requirements but rather gives several alternative construction requirements that are considered appropriate. Acceptable Top Rail and Mid-rail materials include:

A. 1-inch x 1-inch x 1/8-inch structural steel angle
B. 1-inch x 0.070-inch wall steel tubing
C. 1.990-inch x 0.058-inch wall aluminum tubing
D. 2-inch x 4-inch lumber

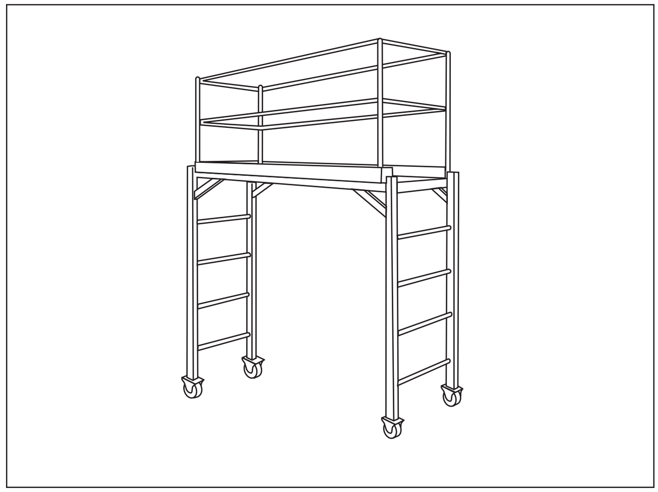

Fig. 3: Manually Propelled Scaffold

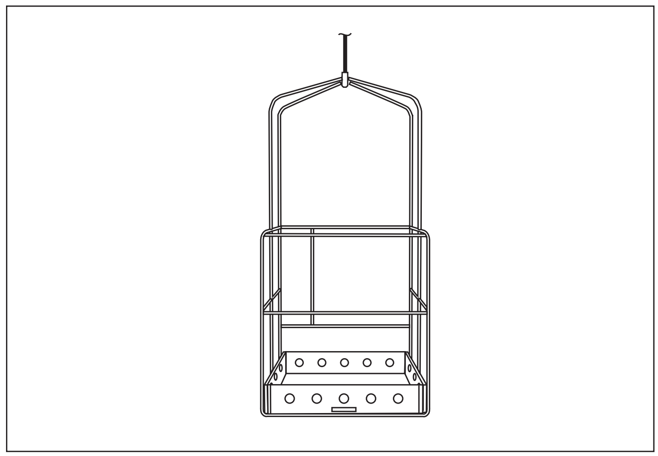

Fig. 4: Single-Point Suspension Scaffold

Other arrangements of Guardrail System construction is acceptable if it has sufficient strength to withstand a concentrated 200-pound force applied in any direction, except upwards, without failure. In addition, the posts supporting the Guardrails must not be spaced more than 10-feet apart. See Figures 3 and 4.

Additional Sources of Guardrail Requirements

Additional American National Standards that include Guardrail/Handrail requirements include:

American National Standard for Construction and Demolition Operations – Safety Requirements for Temporary Floor Holes, Wall Openings, Stairways and Other Unprotected Edges, ANSI A10.18 (1996)

American National Standard for Vehicle-Mounted Elevating and Rotating Aerial Devices, ANSI A92.2 (1990)
American National Standard for Manually Propelled Elevating Aerial Platforms, ANSI A92.3 (1990)
American National Standard for Boom-Supported Elevating Work Platforms, ANSI A92.5 (1992)
American National Standard for Self-Propelled Elevating Work Platforms, ANSI A92.6 (1999)
American National Standard for Airline Ground Support Vehicle-Mounted Vertical Lift Devices, ANSI A92.7 (1990)
American National Standard Safety Requirements for Workplace Floor and Wall Openings, Stairs and Railing Systems, ANSI A1264.1 (1995)
Overhead and Gantry Cranes, ASME B30.17 (1992)
Safety Standard for Low Lift and High Lift Trucks, ASME B56.1 (2000)

Table 1 Summarizes the Guardrail/Handrail requirements contained in these standards.

Guardrail/Handrail strength requirements are not the only criteria to be researched before establishing new criteria for an updated national engineering standard. Other areas of research might include the human factors literature and human pushing capability, the intended use of the product and any foreseeable misuses. The stability of a mobile ladder stand or platform is another unique feature to consider since the product will likely overturn before the maximum guardrail load is applied.

Table 1: Railing Strength Requirements

Standard	Top Rail Strength Requirement (concentrated load)	Mid-Rail Strength Requirement (concentrated load)
A10.18 (1996)	200 lbs applied outward or downward	(None)
A92.2 (1990)	300lbs	300 lbs
A92.3 (1990) (Fig.5)	300 lbs applied outward or downward	300 lbs applied outward or downward
A92.5 (1992) (Fig. 6)	300 lbs applied outward or downward	300 lbs applied outward or downward
A92.6 (1999) (Fig. 7)	300 lbs applied in any direction	300 lbs applied in any direction
A92.7 (1990) (Fig. 8)	300 lbs applied outward or downward	300 lbs applied outward or downward
A1264.1 (1995) (Fig. 9)	200 lbs applied in any direction except upward	160 lbs
B30.17 (1992)	200 lbs applied in any direction except upward	160 lbs
B56.1 (2000) (Fig. 10)	200 lbs applied horizontally No permanent deformation.	(None)

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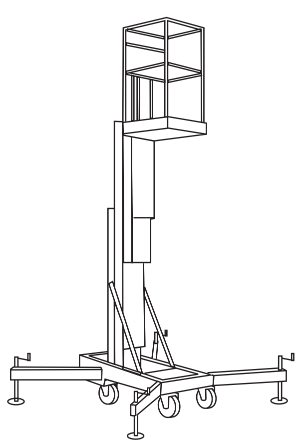

Fig. 5: Manually Propelled Elevating Aerial Platform

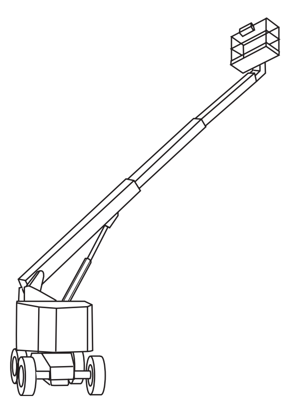

Fig. 6: Boom-Supported Elevating Work Platform

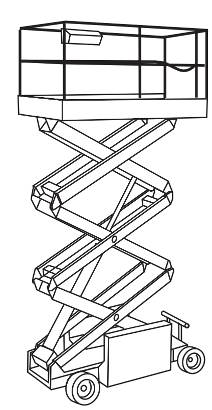

Fig. 7: Self-Propelled Elevating Work Platform

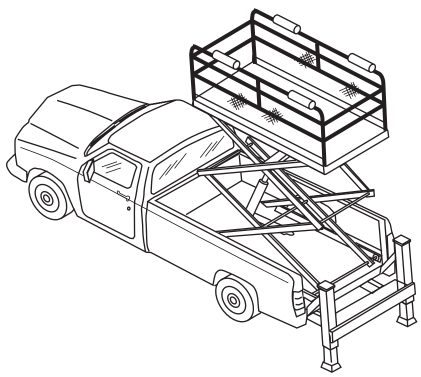

Fig. 8: Airline Ground Support Vehicle-Mounted Vertical Lift Device

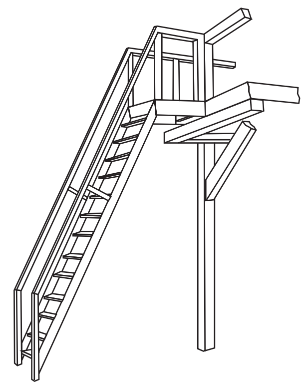

Fig. 9: Open-Sided Floor with Stairway

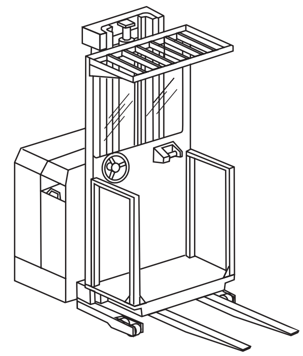

Fig. 10: High Lift Order Picker Forklift Truck

In the Next SAFE Journal Edition:

Case Study:Tipover of a self-propelled elevating work platform

The stability and design-for-safety for a self-propelled elevating work platform is examined. Many times a strict reading of a safety standard applying to a product is not enough to fully understand the intended spirit and safety goals that went into its development. In fact, language that appears in some safety standards is misunderstood and misused by engineers and product designers in the development of a product, sometimes resulting in serious safety deficiencies. Some safety standards attempt to prevent misunderstanding by providing explicit or implicit rationale into the standard. Often, current members of safety standards committees must deal with frequent requests for interpretation, and are at a loss when asked to give rationale for language that was developed decades earlier. Poorly worded safety standards can result in products that not only do not meet the spirit of the code, but that can present dangers that would otherwise have not existed. Second, hazards of equal level are often treated unequally, or ignored. Finally, it is important for the developers of safety standards to become familiar with safety concepts and requirements presented in other safety standards that may be applicable to the product addressed in their standard. This transfer of safety technology can be important in the development of a safety standard and can cut the standards development time drastically.

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In the next issue of the **SAFE JOURNAL** Harry R. Smith [principal, HRS Technical Services; Crete, IL (708) 672 – 6136; email: safetysmith@sbcglobal.net] will conclude his four-part series aimed at acquainting the reader with **P**rogrammable **L**ogic **C**ontroller (PLC) basics and a contemplation of their role in control system safety. It will address some important safety considerations when a design approach involves the use of a PLC in place of conventional relay-type control.

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