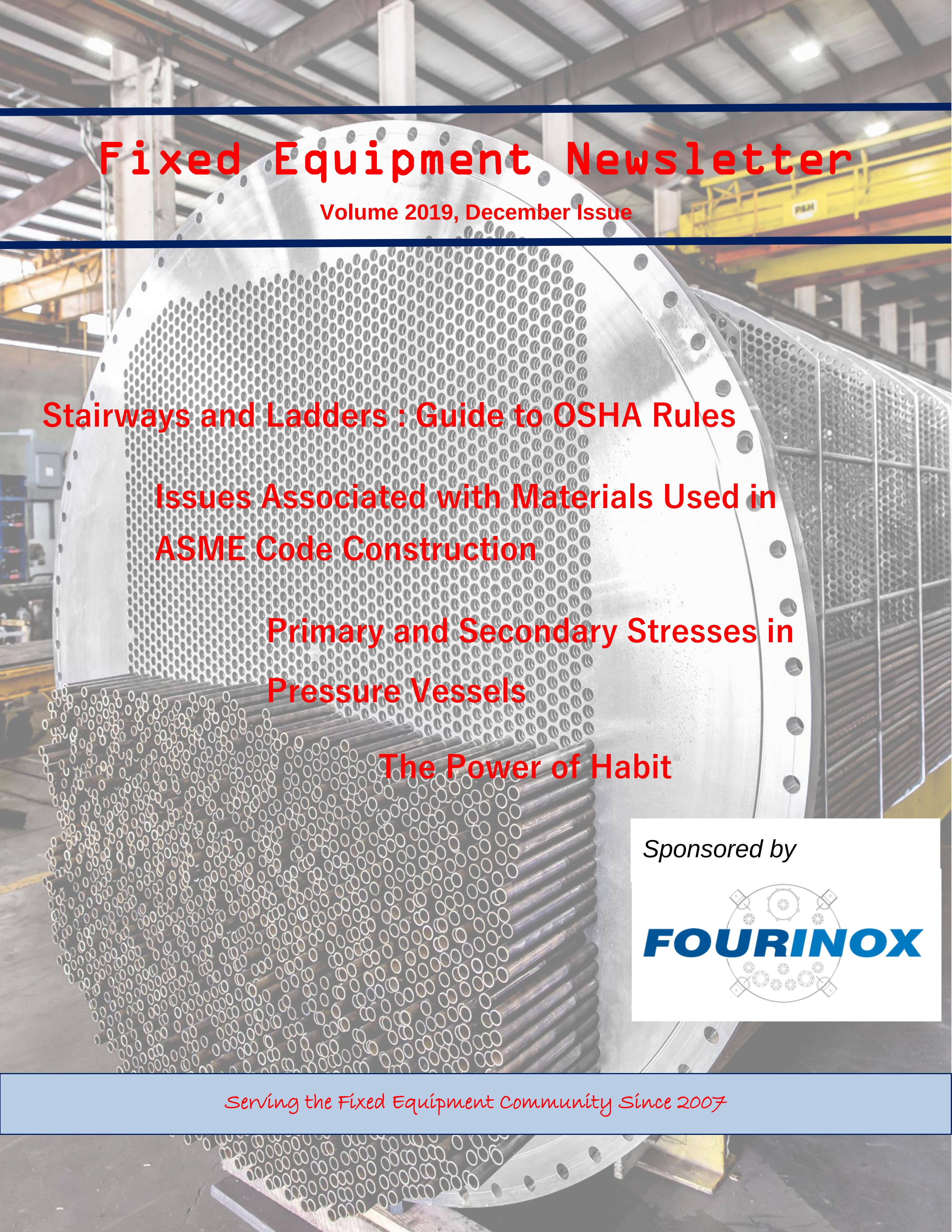

Fixed Equipment Newsletter

Volume 2019, December Issue

Stairways and Ladders : Guide to OSHA Rules

Issues Associated with Materials Used in ASME Code Construction

Primary and Secondary Stresses in Pressure Vessels

The Power of Habit

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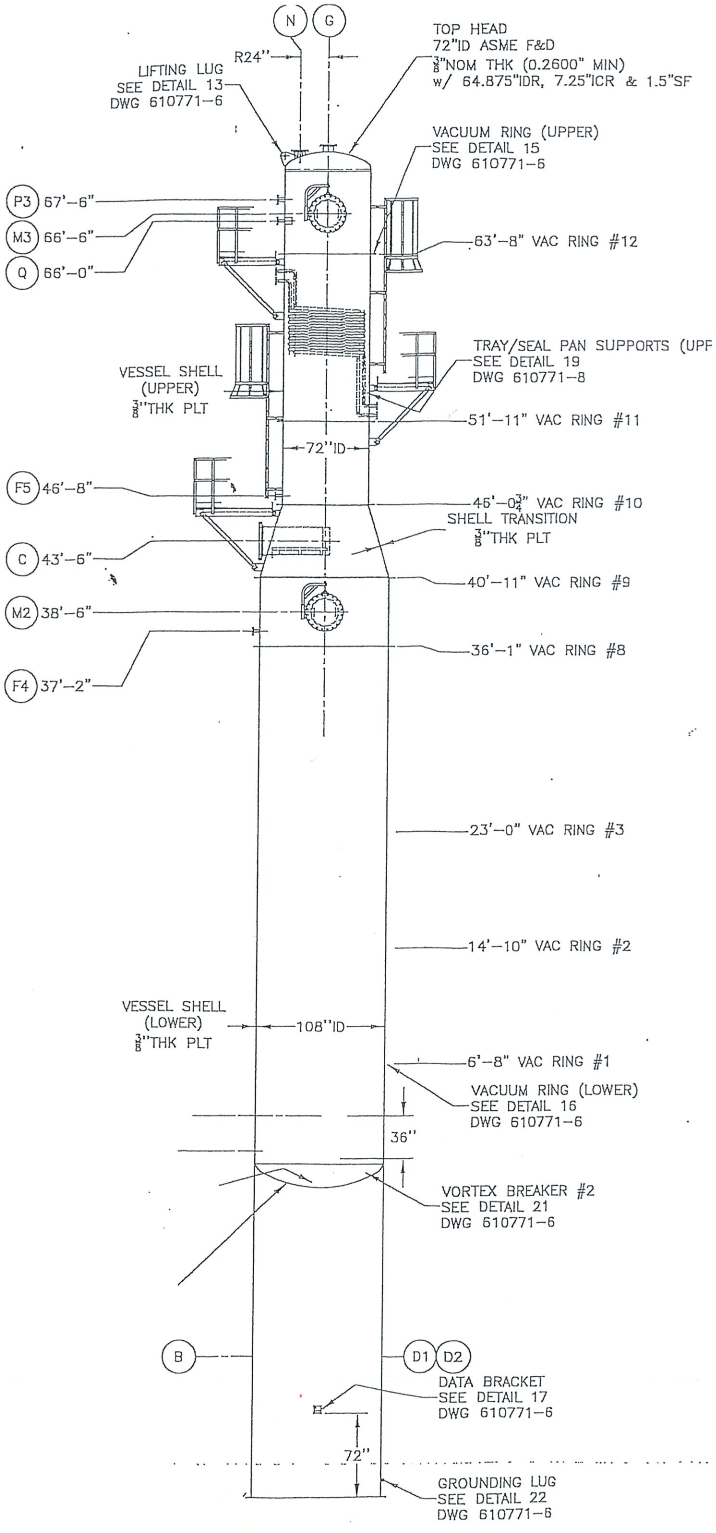

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From The Editor's Desk:

They say you can't teach an old dog a new trick, but sometimes you can upgrade your dog. Innovations, such as twisted tubes, expanded metal baffles, graphene-coated surfaces, and more are improving heat exchanger and condenser performance, making some upgrades worth considering.

Graphene is one improvement that could be game-changing for the power industry, but has little to do with the physical design of a condenser. Instead, it works by changing how steam condenses on the tubes inside heat exchangers. Water vapor commonly condenses in two ways: it can form a film on wetting surfaces, or it can form drops on non-wetting surfaces. When a water film is formed and coats the surface of the condenser tubes, it impedes heat transfer and reduces efficiency. Therefore, promoting droplet formation rather than film formation is one way to improve condenser efficiency.

Graphene is the thinnest material known to man – just one atom thick – but it is also incredibly strong (about 200 times stronger than steel). It is very flexible and is also an excellent conductor of heat and electricity, but it isn't cheap. At a price of roughly $\$60/\text{in}^2$, graphene is currently too expensive to justify the cost of coating condenser tubes.

However, a graphene coating could enhance heat transfer four-fold compared to film-wise condensation, and by some estimates that could lead to a 2% to 3% improvement in overall power plant efficiency. Improving efficiency by that amount would result in annual fuel savings of more than $1 million for the average coal-fired power plant. It could also help plants reduce emissions and meet Clean Power Plan requirements.

Therefore, when the price of graphene decreases – which could occur in next couple of years as production capacity increases and production costs decline – graphene coated condenser tubes could find a market eager for an upgrade. And the researchers aren't done yet; they remain hopeful that by optimizing operating conditions, the heat transfer recorded through graphene-coated tubes could be five to seven times better than that of noncoated tubes.

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THE GRAPHIC ON THE COVER PAGE HAS BEEN PROVIDED BY BRASK IN SULPHUR, LOUISIANA.

In this issue…

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STAIRWAYS AND LADDERS : GUIDE TO OSHA RULES

INTRODUCTION

Working on and around stairways and ladders is hazardous. Stairways and ladders are major sources of injuries and fatalities among construction workers for example, and many of the injuries are serious enough to require time off the job. OSHA rules apply to all stairways and ladders used in construction, alteration, repair, painting, decorating and demolition of worksites covered by OSHA's construction safety and health standards. This article is an overview of OSHA Standard 3124-12R for Stairways and Ladders.

GENERAL REQUIREMENT

These rules specify when employers must provide stairways and ladders. In general, the standards require the following:

- When there is a break in elevation of 19 inches or more and no ramp, runway, embankment or personnel hoist is available, employers must provide a stairway or ladder at all worker points of access.
- When there is only one point of access between levels, employers must keep it clear of obstacles to permit free passage by workers. If free passage becomes restricted, employers must provide a second point of access and ensure that workers use it.
- When there are more than two points of access between levels, employers must ensure that at least one point of access remains clear.

In addition, employers must install all stairway and ladder fall protection systems required by these rules and ensure that their worksite meets all requirements of the stairway and ladder rules before employees use stairways or ladders.

Note: The standard does not apply to ladders specifically manufactured for scaffold access and egress, but does apply to job-made and manufactured portable ladders intended for general purpose use.

RULES FOR LADDERS

All Ladders

The following rules apply to *all ladders:*

- Maintain ladders free of oil, grease and other slipping hazards.
- Do not load ladders beyond their maximum intended load nor beyond their manufacturer's rated capacity.
- Use ladders only for their designed purpose.
- Use ladders only on stable and level surfaces unless secured to prevent accidental movement.
- Do not use ladders on slippery surfaces unless secured or provided with slip-resistant feet to prevent accidental movement. Do not use slip resistant feet as a substitute for exercising care when placing, lashing or holding a ladder upon slippery surfaces.
- Secure ladders placed in areas such as passageways, doorways or driveways, or where they can be displaced by workplace activities or traffic to prevent accidental movement. Or use a barricade to keep traffic or activity away from the ladder.

- Keep areas clear around the top and bottom of ladders.
- Do not move, shift or extend ladders while in use.
- Use ladders equipped with nonconductive side rails if the worker or the ladder could contact exposed energized electrical equipment.
- Face the ladder when moving up or down.
- Use at least one hand to grasp the ladder when climbing.
- Do not carry objects or loads that could cause loss of balance and falling.

In addition, the following general requirements apply to all ladders, including ladders built at the jobsite:

- Double-cleated ladders or two or more ladders must be provided when ladders are the only way to enter or exit a work area where 25 or more employees work or when a ladder serves simultaneous two-way traffic.
- Ladder rungs, cleats and steps must be parallel, level and uniformly spaced when the ladder is in position for use.
- Rungs, cleats and steps of portable and fixed ladders (except as provided below) must not be spaced less than 10 inches apart, nor more than 14 inches apart, along the ladder's side rails.
- Rungs, cleats and steps of step stools must not be less than 8 inches apart, nor more than 12 inches apart, between center lines of the rungs, cleats and steps.
- Rungs, cleats and steps at the base section of extension trestle ladders must not be less than 8 inches nor more than 18 inches apart, between center lines of the rungs, cleats and steps. The rung spacing on the extension section must not be less than 6 inches nor more than 12 inches.
- Ladders must not be tied or fastened together to create longer sections unless they are specifically designed for such use.
- When splicing side rails, the resulting side rail must be equivalent in strength to a one-piece side rail made of the same material.
- Two or more separate ladders used to reach an elevated work area must be offset with a platform or landing between the ladders, except when portable ladders are used to gain access to fixed ladders.
- Ladder components must be surfaced to prevent snagging of clothing and injury from punctures or lacerations.
- Wood ladders must not be coated with any opaque covering except for identification or warning labels, which may be placed only on one face of a side rail.

Note: A competent person must inspect ladders for visible defects periodically and after any incident that could affect their safe use.

Specific Types of Ladders

- Do not use single-rail ladders.
- Use non-self-supporting ladders at an angle where the horizontal distance from the top support to the foot of the ladder is approximately one-quarter of the working length of the ladder.
- Use wooden ladders built at the jobsite with spliced side rails at an angle where the horizontal distance is one-eighth of the working length of the ladder.

In addition, the top of a non-self-supporting ladder must be placed with two rails supported equally unless it is equipped with a single support attachment.

Stepladders

- Do not use the top or top step of a stepladder as a step.
- Do not use cross bracing on the rear section of stepladders for climbing unless the ladders are designed and provided with steps for climbing on both front and rear sections.
- Metal spreader or locking devices must be provided on stepladders to hold the front and back sections in an open position when ladders are being used.

Portable Ladders

The minimum clear distance between side rails for all portable ladders must be 11.5 inches.

In addition, the rungs and steps of portable metal ladders must be corrugated, knurled, dimpled, coated with skid-resistant material or treated to minimize slipping.

Non-self-supporting and self-supporting portable ladders must support at least four times the maximum intended load; extra heavy-duty type 1A metal or plastic ladders must sustain 3.3 times the maximum intended load. To determine whether a self-supporting ladder can sustain a certain load, apply the load to the ladder in a downward vertical direction with the ladder placed at a horizontal angle of 75.5 degrees.

When portable ladders are used for access to an upper landing surface, the side rails must extend at least 3 feet above the upper landing surface. When such an extension is not possible, the ladder must be secured and a grasping device such as a grab rail must be provided to assist workers in mounting and dismounting the ladder. A ladder extension must not deflect under a load that would cause the ladder to slip off its supports.

Fixed Ladders

If the total length of the climb on a fixed ladder equals or exceeds 24 feet, the ladder must be equipped with ladder safety devices; OR self-retracting lifelines and rest platforms at intervals not to exceed 150 feet; OR a cage or well and multiple ladder sections with each ladder section not to exceed 50 feet in length. These ladder sections must be offset from adjacent sections and landing platforms must be provided at maximum intervals of 50 feet. In addition, fixed ladders must meet the following requirements:

- Fixed ladders must be able to support at least two loads of 250 pounds each, concentrated between any two consecutive attachments. Fixed ladders also must support added anticipated loads caused by ice buildup, winds, rigging and impact loads resulting from using ladder safety devices.
- Individual rung/step ladders must extend at least 42 inches above an access level or landing platform either by the continuation of the rung spacings as horizontal grab bars or by providing vertical grab bars that must have the same lateral spacing as the vertical legs of the ladder rails.
- Each step or rung of a fixed ladder must be able to support a load of at least 250 pounds applied in the middle of the step or rung.
- Minimum clear distance between the sides of individual rung/step ladders and between the side rails of other fixed ladders must be 16 inches.
- Rungs of individual rung/step ladders must be shaped to prevent slipping off the end of the rungs.
- Rungs and steps of fixed metal ladders manufactured after March 15, 1991, must be corrugated, knurled, dimpled, coated with skid-resistant material or treated to minimize slipping.
- Minimum perpendicular clearance between fixed ladder rungs, cleats, and steps and any obstruction behind the ladder must be 7 inches, except that the clearance for an elevator pit ladder must be 4.5 inches.

- Minimum perpendicular clearance between the centerline of fixed ladder rungs, cleats and steps, and any obstruction on the climbing side of the ladder must be 30 inches. If obstructions are unavoidable, clearance may be reduced to 24 inches, provided a deflection device is installed to guide workers around the obstruction.
- Step-across distance between the center of the steps or rungs of fixed ladders and the nearest edge of a landing area must be no less than 7 inches and no more than 12 inches. A landing platform must be provided if the step-across distance exceeds 12 inches.
- Fixed ladders without cages or wells must have at least a 15-inch clearance width to the nearest permanent object on each side of the centerline of the ladder.
- Fixed ladders must be provided with cages, wells, ladder safety devices or self-retracting lifelines where the length of climb is less than 24 feet but the top of the ladder is at a distance greater than 24 feet above lower levels.
- Side rails of through or side-step fixed ladders must extend 42 inches above the top level or landing platform served by the ladder. Parapet ladders must have an access level at the roof if the parapet is cut to permit passage through it. If the parapet is continuous, the access level is the top of the parapet.
- Steps or rungs for through-fixed-ladder extensions must be omitted from the extension; and the extension of side rails must be flared to provide between 24 inches and 30 inches clearance between side rails.
- When safety devices are provided, the maximum clearance distance between side rail extensions must not exceed 36 inches.
- Fixed ladders must be used at a pitch no greater than 90 degrees from the horizontal, measured from the back side of the ladder.

Cages for Fixed Ladders

The requirements for cages for fixed ladders are as follows:

Horizontal bands must be fastened to the side rails of rail ladders or directly to the structure, building or equipment for individual-rung ladders.

Vertical bars must be on the inside of the horizontal bands and must be fastened to them.

Cages must not extend less than 27 inches, or more than 30 inches from the centerline of the step or rung and must not be less than 27 inches wide.

Insides of cages must be clear of projections.

Horizontal bands must be spaced at intervals not more than 4 feet apart measured from centerline to centerline.

Vertical bars must be spaced at intervals not more than 9.5 inches, measured centerline to centerline.

Bottoms of cages must be between 7 feet and 8 feet above the point of access to the bottom of the ladder. The bottom of the cage must be flared not less than 4 inches between the bottom horizontal band and the next higher band.

Tops of cages must be a minimum of 42 inches above the top of the platform or the point of access at the top of the ladder. There must be a way to access the platform or other point of access.

Wells for Fixed Ladders

The requirements for wells for fixed ladders are as follows:

- Wells must completely encircle the ladder.

- Wells must be free of projections.
- Inside faces of wells on the climbing side of the ladder must extend between 27 inches and 30 inches from the centerline of the step or rung.
- Inside widths of wells must be at least 30 inches.
- Bottoms of wells above the point of access to the bottom of the ladder must be between 7 feet and 8 feet.

Ladders Safety Devices and Related Support Systems for Fixed Ladders

The connection between the carrier or lifeline and the point of attachment to the body belt or harness must not exceed 9 inches in length. In addition, ladder safety devices and related support systems on fixed ladders must conform to the following:

- All safety devices must be able to withstand, without failure, a drop test consisting of a 500-pound weight dropping 18 inches.
- All safety devices must permit the worker to ascend or descend without continually having to hold, push or pull any part of the device, leaving both hands free for climbing.
- All safety devices must be activated within 2 feet after a fall occurs and limit the descending velocity of an employee to 7 feet/second or less.

Requirements for Mounting Ladders Safety Devices for Fixed Ladders

The requirements for mounting ladder safety devices for fixed ladders are as follows:

- Mountings for rigid carriers must be attached at each end of the carrier, with intermediate mountings spaced along the entire length of the carrier, to provide the necessary strength to stop workers' falls.
- Mountings for flexible carriers must be attached at each end of the carrier. Cable guides for flexible carriers must be installed with a spacing between 25 feet and 40 feet along the entire length of the carrier, to prevent wind damage to the system.
- Design and installation of mountings and cable guides must not reduce the strength of the ladder.
- Side rails and steps or rungs for side-step fixed ladders must be continuous in extension.

Defective Ladders

Ladders needing repairs are subject to the following rules:

- Portable ladders with structural defects - such as broken or missing rungs, cleats or steps, broken or split rails, corroded components or other faulty or defective components - must immediately be marked defective or tagged with "Do Not Use" or similar language and withdrawn from service until repaired.
- Fixed ladders with structural defects - such as broken or missing rungs, cleats or steps, broken or split rails or corroded components - must be withdrawn from service until repaired.
- Defective fixed ladders are considered withdrawn from use when they are immediately tagged with "Do Not Use" or similar language, *or* marked in a manner that identifies them as defective, *or* blocked - such as with a plywood attachment that spans several rungs.
- Ladder repairs must restore the ladder to a condition meeting its original design criteria before the ladder is returned to use.

RULES FOR STAIRWAYS

The rules covering stairways and their components generally depend on how and when stairs are used. Specifically, there are rules for stairs used during construction and stairs used temporarily during construction, as well as rules governing stair rails and handrails.

Stairways Used During Construction

The following requirements apply to all *stairways used during construction:*

- Stairways that will not be a permanent part of the building under construction must have landings at least 30 inches deep and 22 inches wide at every 12 feet or less of vertical rise.
- Stairways must be installed at least 30 degrees - and no more than 50 degrees - from the horizontal.
- Variations in riser height or stair tread depth must not exceed 1/4 inch in any stairway system, including any foundation structure used as one or more treads of the stairs.
- Doors and gates opening directly onto a stairway must have a platform that extends at least 20 inches beyond the swing of the door or gate.
- Metal pan landings and metal pan treads must be secured in place before filling.
- Stairway parts must be free of dangerous projections such as protruding nails.
- Slippery conditions on stairways must be corrected.
- Workers must not use spiral stairways that will not be a permanent part of the structure.

Temporary Stairs

The following requirements apply to *stairways used temporarily during construction.*

Except during construction of the stairway,

- Do not use stairways with metal pan landings and treads if the treads and/or landings have not been filled in with concrete or other materials unless the pans of the stairs and/or landings are temporarily filled in with wood or other materials. All treads and landings must be replaced when worn below the top edge of the pan.
- Do not use skeleton metal frame structures and steps (where treads and/or landings will be installed later) unless the stairs are fitted with secured temporary treads and landings.

Note: Temporary treads must be made of wood or other solid material and installed the full width and depth of the stair.

Stair Rails

The following general requirements apply to all stair rails:

- Stairways with four or more risers or rising more than 30 inches in height - whichever is less - must be installed along each unprotected side or edge. When the top edge of a stair rail system also serves as a handrail, the height of the top edge must be no more than 37 inches nor less than 36 inches from the upper surface of the stair rail to the surface of the tread.
- Stair rails installed after March 15,1991, must be not less than 36 inches in height.
- Top edges of stair rail systems used as handrails must not be more than 37 inches high nor less than 36 inches from the upper surface of the stair rail system to the surface of the tread. (If installed before March 15, 1991, not less than 30 inches).

- Stair rail systems and handrails must be surfaced to prevent injuries such as punctures or lacerations and to keep clothing from snagging.
- Ends of stair rail systems and handrails must be built to prevent dangerous projections, such as rails protruding beyond the end posts of the system.

In addition,

- Unprotected sides and edges of stairway landings must have standard 42-inch guardrail systems.
- Intermediate vertical members, such as balusters used as guardrails, must not be more than 19 inches apart.
- Other intermediate structural members, when used, must be installed so that no openings are more than 19 inches wide.
- Screens or mesh, when used, must extend from the top rail to the stairway step and along the opening between top rail supports.

Handrails

Requirements for handrails are as follows:

- Handrails and top rails of the stair rail systems must be able to withstand, without failure, at least 200 pounds of weight applied within 2 inches of the top edge in any downward or outward direction, at any point along the top edge.
- Handrails must not be more than 37 inches high nor less than 30 inches from the upper surface of the handrail to the surface of the tread.
- Handrails must provide an adequate handhold for employees to grasp to prevent falls.
- Temporary handrails must have a minimum clearance of 3 inches between the handrail and walls, stair rail systems and other objects.
- Stairways with four or more risers, or that rise more than 30 inches in height - whichever is less - must have at least one handrail.
- Winding or spiral stairways must have a handrail to prevent use of areas where the tread width is less than 6 inches.

Midrails

Midrails, screens, mesh, intermediate vertical members or equivalent intermediate structural members must be provided between the top rail and stairway steps to the stair rail system. When midrails are used, they must be located midway between the top of the stair rail system and the stairway steps.

References:

OSHA 3124-12R 2003

CoDesign Engineering Learning Center

PROCESS EQUIPMENT AND PIPING SYSTEMS

This course aims to provide engineers in process plants with the skills necessary to design and build facilities that can be safely and effectively operated and maintained while complying with all regulatory requirements, industry codes and standards, and company policies and procedures. The course covers selection and mechanical design of pressure equipment, thermal equipment, piping systems and machinery (– pumps, compressors and drives). It also emphasizes the importance of interactions and common understanding by engineering, operations and maintenance groups of the equipment design aspects and envelopes and the criticality of operating and maintaining the equipment within its design envelopes.

Topics Covered:

- Overview of process equipment
- Process plant layout and design
- Materials used in process equipment
- Codes and Standards
- Piping & Instrumentation diagrams
- Piping fundamentals
- Pressure vessels
- Heat Exchangers
- Boilers and boiler accessories
- Gas turbines
- Steam turbines, condensers and cooling towers
- Pumps and compressors
- Aboveground storage tanks
- Overpressure protection
- Valves

This is generally organized as on-site classroom training and typically lasts four days. The course contents described above can be tailored to suit specific requirements.

If you are interested and would like to know more about the on-site training, please contact us at training@codesignengg.com.

ISSUES ASSOCIATED WITH MATERIALS USED IN ASME CODE CONSTRUCTION – PART 1

INTRODUCTION

The performance over time of various ferrous and non-ferrous alloys used in construction of pressure vessels may be influenced by many factors – ranging from the processes involved in their fabrication and installation to changes in material structure or direct damage to material related to operation in the intended service. If the vessel is to provide a reasonably long period of safe operation, then the designers must be aware of any potential change in the material's properties related to fabrication, installation, or service as they go about selecting materials for the pressure vessel. ASME Code does not mandate that all of the various metallurgical phenomena and environmental effects that can influence material performance be considered in the design of the pressure vessel. However, such consideration is a part of good engineering judgment that should be exercised, and this article is intended to provide the designers of such vessels with assistance in the material selection process.

The issues related with materials used in the construction of most ASME Code pressure vessels can be classified into seven broad categories. They are:

1. Metallurgical changes:

   Materials used in construction of pressure vessels have a well-characterized database from which allowable stresses can be developed. However, there are certain manufacturing and installation processes, as well as many service conditions, that can affect the macrostructure and the microstructure of these materials and, in doing so, modify the behavior of these materials in service. These are the "bulk" effects where large parts of an entire structure have been altered – and these effects are sometimes called metallurgical phenomena. The various phenomena of potential interest are as follows:

   a. Graphitization
   b. Spheroidization (softening)
   c. Temper embrittlement
   d. Strain aging
   e. Cold working (cold strain)
   f. Relaxation cracking (strain-induced precipitation hardening)
   g. 885^{o}F embrittlement
   h. Sigma phase embrittlement
   i. Laves and Laves phase precipitation
   j. Sensitization (carbide formation)
   k. Thermal aging embrittlement
   l. Radiation embrittlement
   m. Solidification cracking

2. Uniform corrosion:

   This is the simplest form of environmental damage – one that generally results in a uniform amount of wall loss over a defined period of time. It can usually be expressed as some amount of wall thickness lost per unit of time (e.g., mils per year). Most Sections of the ASME Code have requirements for corrosion allowance, and uniform corrosion is usually what is addressed. The following are several possible uniform corrosion mechanisms:

   a. General corrosion and wastage

    b. Atmospheric corrosion
    c. Galvanic corrosion
    d. Stray current corrosion
    e. High-temperature corrosion
    f. Soil corrosion
    g. Caustic corrosion
    h. Carbon dioxide corrosion
    i. Concentration cell corrosion
    j. Differential-temperature cell corrosion
    k. Molten salt corrosion
    l. Liquid metal corrosion

3. Localized corrosion:

   Localized corrosion is a broad term describing any one of a number of corrosion processes in which damage takes place at small and well-defined locations on the surface of a material rather than uniformly over the entire surface. A concern with this type of corrosion is that often it is difficult to determine how serious the degree of attack is until leakage at one or more sites on the surface actually occurs. This type of corrosion usually does not lead to catastrophic ruptures typically associated with gross wall loss over a period of time. The following are several mechanisms considered to be forms of localized corrosion:

    a. Pitting corrosion
    b. Filiform corrosion
    c. Crevice corrosion (and denting)
    d. Microbiologically influenced corrosion

4. Metallurgically influenced corrosion:

   This group of corrosion mechanisms involves those cases where the structure of a material has been altered either during fabrication into a component or during relatively longtime exposure to service conditions. Examples of these mechanisms are:

    a. Intergranular corrosion
    b. Dealloying corrosion (dezincification and graphite corrosion)
    c. Grooving

5. Mechanically assisted corrosion:

   These are corrosion-related damage mechanisms in which the process of metal loss is substantially enhanced by the impinging action of a solid, liquid or gas present in the operating environment on the surface of the component containing that environment. The impinging substance may be any impurity, corrosion product, or entrained gas contained within the operating system. The damage caused by any one of these mechanisms tends to be localized, reflecting the influence of variations in the flow pattern of water or other process fluids. Examples of these mechanisms are:

    a. Velocity-affected corrosion
    b. Erosion-corrosion
    c. Impingement corrosion
    d. Cavitation erosion
    e. Corrosion fatigue

6. Environmentally induced embrittlement and cracking:

   This general category of damage could be included in the discussion of some of the other types of damage in which metallurgical changes and corrosion interact. However, because some of the specific types of damage have special significance in the ASME Code construction, they warrant individual coverage to draw attention to their importance. These mechanisms are:

a. Stress corrosion cracking
b. Hydrogen damage
c. Liquid metal embrittlement
d. Caustic embrittlement
e. Flow-accelerated corrosion
f. Sulfur embrittlement

7. Mechanical damage mechanisms

Mechanical damage mechanisms are those mechanisms in which the damage is not controlled by direct electrochemical reactions between the pressure containing material and the substance contained. Instead, the damage occurs to system materials as a result of simple mechanical contact with other materials – or from sudden changes in coolant temperature and/or velocity. Some of the more important damage mechanisms are as follows:

a. Fretting and wear
b. Thermal fatigue
c. Dynamic loading
d. Anisotropy

This article will only discuss the issues associated with the metallurgical changes that can occur in service. Part 2 will deal with uniform corrosion, localized corrosion, and metallurgically influenced corrosion, while Part 3 will address mechanically assisted corrosion, environmentally induced embrittlement and cracking, and mechanical damage mechanisms.

METALLURGICAL CHANGES THAT CAN OCCUR IN SERVICE

Graphitization

Graphitization is a process in which some portion of carbon, present in the iron carbide that forms in the microstructure of carbon or carbon-0.5Mo steels during virtually all standard heat treatment for these steels, dissociates from the carbides and forms separate particles of free carbon, or graphite. This change will occur only over a relatively long period of time when the steel is operating in the temperature range of 800°F to 1100°F and, depending on the nature of distribution of the graphite particles in the microstructure, can result in a substantial loss of the material’s strength and ductility.

The graphite particles may be randomly distributed throughout the structure, in which case the effect on the material performance will be minimal, or they may be aligned along a certain preferred planes in the structure, in which case the loss of ductility can be severe, leading to unexpected failure of the component.

Experience has shown that for the C-Mo steels, the temperatures of greatest susceptibility are approximately 50°F higher than for the plain carbon steels. The addition of approximately 0.5 weight % Cr to the steel will stabilize the carbides in the microstructure and prevent the occurrence of graphitization, which is an inducement to use other grades of steel containing Cr for service at elevated temperatures.

Spheroidization (Softening)

Graphitization and spheroidization are competing processes in which carbide phases of certain steels are altered as the result of prolonged exposure to temperatures in the range of 800°F to 1400°F. In the case of spheroidization, the carbide does not break down to release the carbon, but it changes from an approximately planar shape developed during the original heat treatment to a lower energy spheroidal shape, resulting in some loss of both room temperature and elevated temperature strength (by as much as 30%), but an increase in ductility.

Spheroidization may occur in any carbon or alloy steel, including the 9% Cr and 12% Cr creep strength-enhanced ferritic steels. Experience over the years has shown the following:

a. Annealed steels are more resistant to spheroidization than normalized steels, since they are intentionally heat treated to exist in a more stable condition.
b. Coarse-grained steels are more resistant to spheroidization than fine-grained steels.
c. Fine-grained silicon-killed steels are more resistant than aluminum-killed steels.

Temper Embrittlement

Temper embrittlement is a metallurgical phenomenon that can occur in several different classes of steel, including plain carbon steels, low alloy steels, and martensitic steels, in which the toughness of the material drops significantly when subjected to prolonged exposure to within what would be considered a normal range for either heat treatment or service.

The mechanisms of embrittlement vary somewhat with the type of steel involved, but in the application of materials for ASME Code construction, the more significant embrittlement is that which occurs in some low alloy steels during long time exposure in the temperature range of 650°F to 1100°F. Temper embrittlement can occur either during fabrication or during prolonged exposure in the embrittling temperature range during service.

The embrittled material is most vulnerable during equipment startups and shutdowns, during which times it is most likely to fracture in a brittle manner when rapidly loaded at temperatures within or below the transition range temperature.

Various methods have been devised for controlling the susceptibility to temper embrittlement through control of chemical composition, with the use of J and X factors having achieved a fairly broad range of acceptance. Through the use of these factors, the amounts of the most deleterious elements are limited to levels known to confer a high degree of resistance to temper embrittlement. These factors are defined as follows:

J factor (base metal) = (Si + Mn) x (P + Sn) x 10,000
≤ 150 (elements calculated as in wt/%)
X factor (weld metal) = (10P + 5Sb + 4Sn + As)/ 100
≤ 15 (elements calculated in ppm)

In addition to material composition, PWHT procedures should be carefully selected and/or qualified to avoid temper embrittlement before exposing the material to service conditions.

The effects of temper embrittlement can be reversed by heating the affected material to a minimum temperature of 1150°F and holding for 2 hours per inch of thickness, followed by rapid cooling to room temperature. However, the material will quickly re-embrittle if it is re-exposed to the conditions that caused the embrittlement in the first place.

Strain Aging

Strain aging can be defined as an age-hardening phenomenon in which the tensile strength and hardness of a cold worked material are increased and the ductility reduced when that material is exposed to moderately elevated temperatures, normally as a result of service, although it can also occur during fabrication. The most common mechanism for the aging is the precipitation of nitrides at dislocations and other crystalline defects created during the cold working of the material, and it is for this reason that strain age damage is far more prevalent in older versions (pre-1980) of carbon and C-0.5Mo steels, where control of the nitrogen content was less effective.

The effects of strain aging can be minimized or eliminated by a stress-relieving heat treatment following the cold working, where the temperature of the stress relief is sufficiently high to substantially reduce the number of available initiation sites for the nitride precipitation.

Cold Working (Cold Strain)

Cold working is any process of plastic deformation of a metal that occurs at temperatures below the material's transformation or recrystallization temperature and in which material is hardened by the strain. As the hardness of a cold-worked material is increased, the ductility of the material decreases.

Cold work effects are particularly pronounced in alloys like austenitic (300 series) stainless steels. When austenitic stainless steels that have been moderately to heavily cold worked are operated in the creep range (generally above about 1000°F), recrystallization may occur and the grain size can be substantially reduced, particularly if the temperature is limited to a level only slightly above the recrystallization temperature. This can result in an increase in the creep rate, with a corresponding decrease in creep rupture strength.

Cold work contributes to certain types of microstructural instability. In addition, the residual stresses induced by cold work can substantially increase the risk of cracking in austenitic stainless steels and other austenitic alloys when these materials are exposed to certain types of aggressive environment.

Concern over the effects of cold work has led to the implementation of various requirements in the construction codes for the heat treatment of certain cold-worked materials once a critical level of strain is exceeded. Because of the complexity of the relationship between cold work and material degradation, implementation of the heat treatment rules is not a guarantee that premature failures will be avoided in all situations. Likewise, violation of the limits defined in the rules will not inevitably in the premature failures.

Relaxation Cracking (Strain-Induced Precipitation Hardening)

Relaxation cracking is a condition that may develop in cold-worked or warm-worked austenitic materials when temper-resistant particles precipitate at excess defect sites generated by the cold or warm working operations; these precipitates act to "pin" the defects, which results in a substantial increase in the material's creep strength and hardness. The bulk of the strengthening occurs within the individual grains, while the grain boundaries remain comparatively weak, so that when the material is heated to intermediate temperatures in the range of 950°F to 1400°F, any strains that develop either in response to heat treatments or service temperatures concentrate in the grain boundaries. This can lead to rapid creep crack growth and ultimately failure of the component in a non-ductile fashion.

There is substantial heat-to-heat variability in the relative susceptibility of an alloy to relaxation cracking, but in susceptible heats, the rate of crack growth can be quite rapid if the amount of working and the temperature of exposure are unfavorable. In fact, pressure parts fabricated from susceptible heats of 347H material and 310HCbN have cracked through-wall during heat-up for solution annealing.

885ºF Embrittlement

Upon exposure to elevated temperatures, high chromium stainless steels and the ferrite phase of austenitic and austenitic-ferritic (duplex) stainless steels are subject to a type of embrittlement in which the material hardness increases and the tensile ductility and toughness decrease at and below the service temperature. This metallurgical phenomenon is observed at Cr levels in excess of 10% to 12% and the embrittlement may be due to carbide, nitride, or silicide precipitation, especially at the lower Cr levels, rather than precipitation of alpha prime chromium-rich particles.

The severity of embrittlement increases with increasing Cr content, and the effect is enhanced by certain alloying elements, notably aluminum, molybdenum, and tungsten, which tend to increase and stabilize the ferrite content. While the maximum rate of embrittlement occurs at 885°F, a typical "C" curve time-temperature behavior is observed and some alloys with as little as 15% to 18% chromium have shown significant embrittlement with just a few thousand hours exposure at temperatures as low as 500°F.

The 885°F embrittlement generally becomes apparent first as a reduction in Charpy impact ductile-brittle transition temperature (DBTT), and only in its last stages are changes in strength, hardness, and ductility observed. The embrittlement normally is not a problem at elevated temperatures, but it can become a problem when components are cooled to ambient temperatures.

Sigma Phase Embrittlement

Sigma phase embrittlement is a metallurgical phenomenon in which an iron-chromium intermetallic compound that is hard and brittle forms in certain high alloy steels after prolonged exposure at temperatures ranging from 1050°F to 1700°F. The embrittling effect is observed most immediately at lower temperatures where there is a reduction in tensile ductility and a loss in toughness. The presence of sigma phase is normally less injurious at the higher temperatures where it forms. However, under certain conditions, the presence of large amounts of sigma phase has been linked to significant reductions in creep ductility, with a corresponding reduction in creep life of a component.

Materials typically susceptible to sigma phase formation include the following:

a. 300 series stainless steels including both cast and wrought forms, as well as weld metals
b. 400 series stainless steels, both ferritic and martenisitic types, generally with chromium levels of 17% and more
c. Duplex stainless steels

Factors that influence the rate of sigma phase formation include the amount of delta ferrite present, time within the temperature range of formation, prior cold working, variations in composition due to progressive solidification, increased chromium content, and the presence of ferrite stabilizing elements, particularly molybdenum, niobium and titanium, which act to increase the chromium equivalent, while austenitic stabilizing elements, particularly carbon, nitrogen, nickel and manganese, reduce the rate of sigma phase formation.

It is possible to “de-sigmatize” affected materials by re-solution annealing at a minimum of 1950°F for about 4 hours, followed by a water quench, but the rate of reformation when exposed to temperatures within the susceptible range is rapid.

Laves and Laves Phase Precipitation

Most austenitic (300 series) stainless steels are metastable materials, which means that during elevated temperature service, a range of complex carbides and other noncarbide phases may form, depending on the time and temperature of exposure, the specific alloy composition, and prior cold working or other fabrication process variables. One of those phases is the Laves phase, the formation of which may occur during alloy production or during service, and is another of the metallurgical phenomena that may occur during exposure of austenitic steels containing molybdenum, titanium and niobium, in the temperature range from just above 1100ºF to approximately 1600ºF.

Laves phase precipitates within grains (intra-granularly) or inter-granularly, forming into globular particles or into platelets.

Sensitization (Carbide Formation)

Sensitization involves the precipitation of chromium carbides along the grain boundaries of austenitic (300 series) and ferritic/martensitic (400 series) stainless steels when they are exposed for significant periods of time in the temperature range of about 1000ºF to 1550ºF. The grain boundary precipitation of the chromium carbides typically results in a strengthening of the alloy; however, because the formation of the carbides depletes the material immediately adjacent to the precipitates of chromium, the material can be highly susceptible to intergranular corrosion when exposed to corrosive aqueous environments at lower temperatures.

The rate at which sensitization occurs and the degree of sensitization will depend on the specific material composition and the time and temperature of exposure. For example, the ferritic stainless grades will sensitize much more rapidly than the austenitic grades, due to the difference in diffusion rates in the two different crystal structures. Portions of a weld heat-affected zone in a susceptible material inevitably will be subjected to sensitizing temperatures and this should be considered if the welded component is to be subjected to a corrosive environment.

For high temperature applications, the material will desensitize over time as the chromium from the surrounding material diffuses back into the depleted region, but this process occurs much more slowly than the sensitization itself. Modifications have been made to the composition of some austenitic and ferritic grades to minimize the risk of sensitization, including the reduction of carbon (i.e., the so called L grades) and the introduction of elements such as titanium and niobium that form carbides in preference to the chromium carbide (e.g., Type 321 and Type 347). It should be noted, however, that in high-temperature applications, the presence of “stabilizing” elements such as titanium or niobium will typically retard, but not prevent, the occurrence of sensitization, although the presence of these elements will alter the rate of its development.

Thermal Aging Embrittlement

Several forms of thermally induced embrittlement have previously been covered in graphitization, temper embrittlement, strain-aging embrittlement, 885°F embrittlement, and sigma phase embrittlement. Issues not yet covered within the general subject of thermal aging embrittlement include blue brittleness, quench age embrittlement, stress-relief embrittlement, and tempered-martensite embrittlement. These last four issues all arise during fabrication-related heating activities.

Blue brittleness is an embrittling phenomenon that occurs when plain carbon steels and some alloy steels are heated into the temperature range of 450°F to 700°F. Blue brittleness is an accelerated form of strain-age embrittlement and is characterized by an increase in strength and a marked decrease in ductility and toughness.

Quench-age embrittlement occurs in low carbon steels when the material undergoes hardening in response to the precipitation of carbides at existing dislocations due to differences in the solid solubility of carbon in ferrite at different temperatures. The hardening reaction is made possible by rapid cooling from temperatures slightly below the lower critical transformation temperature, at which temperature the solubility of carbon is substantially greater than at room temperature. As the hardness of the steel increases with increased aging at room temperature, the ductility decreases proportionally. An aging period of several weeks at room temperature is required for maximum embrittlement.

Stress-relief embrittlement is also known as *postweld heat treat cracking* or *reheat cracking*; where this mechanism is active, it will lead to intergranular cracking within the higher-strength portions of the weld zone (e.g., the coarse-grained heat-affected zone and the weld deposit itself) during stress relieving or during subsequent elevated temperature service. The metallurgical phenomenon occurs only in low alloy structural and pressure vessel steels, ferritic creep-resisting steels, austenitic stainless steels, and some nickel-base alloys. In all of these alloys, the rapid precipitation of temper-resistant phases during the early stages of heat treatment or service leads to a significant strengthening of the interior of grains within the material. The creep strain that is the mechanism of stress relief then concentrates within the grain boundary regions, which often are depleted of precipitates, leading to rapid intergranular cracking.

Tempered-martensite embrittlement is a metallurgical phenomenon affecting quenched and tempered high strength low alloy steels over the temperature range of 400°F to 700°F. Tempered-martensite embrittlement is generally thought to be caused by ferrite networks that develop due to the precipitation of cementite platelets along prior-austenite grain boundaries. Steels containing significant percentages of chromium or manganese have the highest potential for this form of embrittlement.

Radiation Embrittlement

Radiation embrittlement is a metallurgical phenomenon affecting most structural materials exposed to high levels of high-energy neutrons, usually within or near the cores of nuclear reactors. The embrittlement is evident as a substantial loss in toughness and ductility, with accompanying gains in strength (hardening). For pressure-boundary materials, the most significant concern is the increase in the ductile-to-brittle transition temperature and a decrease in the upper-shelf energy observed during impact tests.

Extensive research over the years has revealed the following:

a. High-strength steels that have lower initial nil-ductility transition temperatures than low-strength steels are generally less susceptible to radiation embrittlement.

b. Steels with low initial nil-ductility transition temperatures, fine-grain microstructures, and structures with high dislocation densities generally show greater resistance to radiation embrittlement.

c. Steels with tempered-martensite in the microstructures are less susceptible than those with tempered upper bainite or ferritic microstructures.

d. Vacuum degassing and control of alloying elements such as copper, phosphorus, and possibly nickel help to reduce the susceptibility to radiation embrittlement.

Solidification Cracking

Solidification cracking is a form of hot cracking that can occur in weldments of nickel-base alloys. Solidification cracking occurs when alloying elements or impurities are present that segregate during solidification and form low-melting-point liquid films on grain boundaries. Tensile stresses, which build up during solidification and cooling of the weld metal, can cause cracking along the liquid films. Elements that can promote solidification cracking in nickel-base alloys include sulfur, phosphorus, silicon, boron, and zirconium. The problem may appear as macroscopic solidification cracks, typically along the weld centerline, or as microfissures within the weld metal. Solidification cracks may or may not be open to the surface. For a given material, the occurrence of solidification cracking is influenced by weld joint design and weld bead geometry. Solidification cracking is promoted by high heat input, a concave weld bead profile, and a teardrop-shaped weld pool. Heavy restraint, due to thick material or a rigid joint design, will also promote solidification cracking.

References:

ASME Boiler and Pressure Vessel Code, Section II, Part D

PRIMARY AND SECONDARY STRESSES IN PRESSURE VESSELS

INTRODUCTION

The pressure vessel codes define two important ‘classes’ of stress. A primary stress is related to mechanical loading directly and satisfies force and moment equilibrium. Primary stress that exceeds the yield stress by some margin will result in failure. By contrast, secondary stresses are those arising from geometric discontinuities or stress concentrations. For an increasing external load, at any point, both primary and secondary stresses increase in proportion to this load, until the yield point is reached. But secondary stresses are termed self-limiting by the ASME code: that is, once the yield point has been passed locally around the stress concentration, the direct relationship between load and stress is broken, due to the reduced post-yield stiffness of the material. This is in contrast to primaries (sometimes termed ‘load controlled’ stresses) that will continue to increase in overall magnitude, in direct proportion to the applied load, irrespective of the shape of the stress-strain curve, until failure.

In a region away from any discontinuities, only primary stress will arise. The secondary stress cannot arise alone, however - at a discontinuity, the secondary stress will be superimposed on the underlying primary stress. It is worth pointing out the distinction made between primary and secondary stress in the pressure vessel codes is broadly similar to that made between net section and peak stresses identified in the British Standards for the assessment of fabricated structures, as described in previous articles.

Primary Stresses

Primary stress is defined as a normal or shear stress developed by the imposed loading that is necessary to satisfy the laws of equilibrium of external and internal forces and moments. These stresses act over a full cross section of the vessel. The basic characteristic of a primary stress is that it is not self-limiting. Primary stresses that considerably exceed the yield strength will result in failure or at least in gross distortion. A thermal stress is not classified as a primary stress. Primary stresses are generally due to internal or external pressure or produced by sustained external forces and moments. Primary loads typically have the characteristic of being “persistent” loads. That is, the load is not relieved as the system deforms. You might also hear the terms, “following load” or “load control” to describe this phenomenon. In the B31 Codes, the term “sustained load” is used.

Primary stresses are further categorized into a uniform (single value) membrane stress distribution across a cross-section; and a linearly varying, bending stress distribution. These definitions are more ambiguous in the codes than those for primary and secondary stress but are necessary since they have different allowable values. The need for dividing primary stresses into membrane and bending is that the calculated value of the primary bending stress may be allowed to go higher than that of primary general membrane stress.

Primary membrane stress occurs across the entire cross section of the vessel due to mechanical loads such as internal pressure, dead weight, or wind loads. It is remote from discontinuities such as head-shell intersections, cone-cylinder intersections, nozzles and supports. It is so distributed in the structure that no redistribution of load occurs as a result of yielding. Examples of such stresses are a) circumferential and longitudinal stress due to pressure, b) compressive and tensile axial stress due to wind, c) longitudinal stress due to the bending of the horizontal vessel over saddles, d) membrane stress in the center of flat head, e) membrane stress in the nozzle wall with in the area of reinforcement due to pressure or external loads, and f) axial compression due to weight.

A primary bending stress can be defined as a bending stress developed by the imposed loading that is necessary to satisfy the laws of equilibrium of external and internal forces and moments**.** These stresses are due to sustained loads and are capable of causing collapse of the vessel. Like all primary stresses, primary bending must satisfy equilibrium or failure of the component will result. There are relatively few areas where primary bending occurs:

a) bending stress in the center of flat head or in the crown of a dished head, b) bending stress in a shallow conical head, and c) bending stress in the ligaments of closely spaced openings.

Primary membrane stress is divided into general and local categories. A general primary membrane stress is one that is distributed in the structure such that no redistribution of load occurs as a result of yielding. Examples of primary stress are general membrane stress in a circular cylindrical or a spherical shell due to internal pressure or to distributed live loads and the bending stress in the central portion of a flat head due to pressure. Cases arise in which a membrane stress produced by pressure or other mechanical loading and associated with a primary and/or a discontinuity effect would, if not limited, produce excessive distortion in the transfer of load to other portions of the structure. Conservatism requires that such a stress be classified as a local primary membrane stress even though it has some characteristics of a secondary stress.

Secondary Stresses

Secondary stress is any normal or shear stress that develops as a result of material constraint. This type of stress is self-limiting, which means that local yielding can relieve the conditions that cause the stress, and single application of load will not cause failure. Secondary load is also called “strain-controlled” load, and develop at structural discontinuities.

There are two sources of Secondary stress:

1. Temperature
2. Gross structural discontinuity: A discontinuity which increases the stress or strain which affect a relatively large portion of the structure. It significantly affects the overall stress or strain distribution. Examples of Gross Structural Discontinuity are as follows.
    - Dished head Connection to the cylindrical shell
    - Flange connection to the cylindrical shell
    - Nozzle connection to the cylindrical shell
    - Junction between the shells of different diameters
    - Junction between the shells of different thicknesses

    Saddle supports and lifting lugs cause bending stresses to occur across the vessel wall thickness and so are not considered to be local structural discontinuities but gross discontinuity.

Examples of secondary stresses are:

1. Bending stresses at head-to-shell junctions.
2. Bending stress at conical-transition-to-cylindrical-shell junction.
3. Bending stress in the shell at nozzles.
4. Bending stress at vessel supports and external attachments.
5. Thermal stresses produced by temperature gradients in the shell, or by differences in temperature between the nozzle and shell.

Unlike primary stresses, secondary stresses are reduced in magnitude by the local yielding, before gross plastic deformation or bursting can occur. The first application of load during hydrotest will generally suffice to significantly reduce the secondary stresses in a pressure vessel, but subsequent load applications could further reduce the secondary stresses.

A distinction must be made between local primary membrane stresses and secondary stresses. Like secondary stresses, local primary membrane stresses also develop at structural discontinuities, and are essentially self-limiting. However, they are categorized as primary stresses because the plastic deformation associated with the yielding (required to redistribute the local membrane stress) may be excessive.

Therefore, in effect, the membrane component of the stress developed by the self-constraint at structural discontinuities is categorized as a primary stress, whereas the bending component of the stress is categorized as a secondary stress.

ALLOWABLE STRESSES BASED ON FAILURE MODES

Because different modes of failure are associated with primary membrane, primary bending and secondary stress, different allowable values are defined for each. These are not given as absolute values in the pressure vessel codes, but as a proportion of the yield stress of the material in question.

Primary membrane stresses are not allowed to exceed yield otherwise there is the possibility of a catastrophic plastic collapse e.g. a burst under pressure. For a membrane stress, the limiting value will be reached over the full vessel cross-section simultaneously and a margin of safety is included by specifying an allowable membrane stress of 2/3 yield.

The total primary (membrane plus bending) allowable stress is greater, having a value of yield because the bending element means that the stress will only be reached at a location in a localised cross-section, most distant from the neutral axis. Secondary stress can comfortably exceed yield but must be limited to ensure shakedown under cyclic load. Hence the range of secondary stress is limited to twice yield.

The stress limit for secondary stresses is 3.0 times the maximum allowable design stress for the material of construction at the design temperature. Therefore, the secondary stress is permitted to be as high as twice the yield strength, but it is reduced in magnitude by local yielding. Unless a detailed stress analysis is made, structural discontinuities that develop secondary stresses should be separated by a distance of at least 2.5 x R(t)1/2 to avoid additive effects that could increase the total secondary stress above 3.0 times the maximum allowable design stress.

References:

Internet Article – NAFEMS; and other internet sources

API 579: Fitness-for-Service (FFS)

ASME Boiler & Pressure Vessel, Section VIII, Division 1

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THE POWER OF HABIT

“All our life, so far as it has definite form, is but a mass of habits (William James in 1892). Most of the choices we make each day may feel like the products of well-considered decision making, but they’re not. They’re habits. And though each habit means relatively little on its own, over time, the meals we order, what we say to our kids each night, whether we save or spend, how often we exercise, and the way we organize our thoughts and work routine shave enormous impacts on our health, productivity, financial security, and happiness. One paper published by Duke University researcher in 2006 found that more than 40 percent of the actions people performed each day weren’t actual decisions, but habits.”

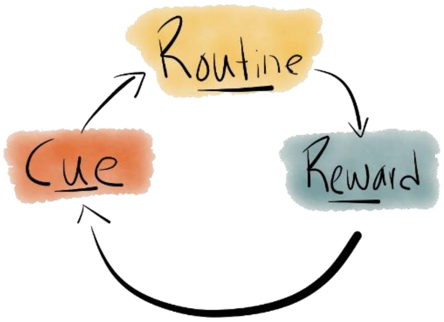
--- From “The Power of Habit” by Charles Duhigg

What are habits?

A habit is just a choice that we deliberately made at some point (how to eat, how often to drink, when to go for a jog, etc), and then stop thinking about, but continue doing — often every day. Put another way, a habit is a formula our brain automatically follows. When I see CUE, I will do ROUTINE in order to get REWARD. By understanding how it happens, you can rebuild those patterns in whichever way you choose.

Habit loops

All habits follow the same, simple, three-step loop:



I. Cues

First, there is a *cue*. This is a trigger that tells your brain to go into automatic mode, and which habit to use. *Cues* can be almost anything, from a visual trigger to a time of day, an emotion, a sequence of thoughts, the company of particular people, etc.

II. Routines

Next, there is the *routine*. This can be physical, mental, or emotional. *Routines* can be incredibly complex or fantastically simple.

III. Rewards

Finally, there is the *reward*. This helps your brain figure out if this particular loop is worth remembering for the future. *Rewards* can range from food or drugs that cause physical sensations, to emotional payoffs, such as the feelings of pride that accompany praise or self-congratulation.

When a habit emerges, the brain stops fully participating in decision making. It stops working so hard, or diverts focus to other tasks. So, unless you deliberately fight a habit — unless you find new routines — the pattern will unfold automatically.

Habits never really disappear. They're encoded into the structures of our brain. The problem is that your brain can't tell the difference between good and bad habits, so if you have a bad one, it's always lurking there, waiting for the right cues and rewards.

Habits = water

There are these two young fish swimming along and they happen to meet an older fish swimming the other way, who nods at them and says "Morning, boys. How's the water?" And the two young fish swim on for a bit, and then eventually one of them looks over at the other and goes "What the hell is water?" - David Foster Wallace

The water is habits: The unthinking choices and invisible decisions that surround us - and which, just by looking at them, become visible again.

Keystone habits

Some habits matter more than others in remaking our lives (or businesses). These are 'keystone habits', and they can influence how people work, eat, play, live, spend, and communicate. Keystone habits teach us that success *doesn't depend on getting every single thing right*, but instead relies on *identifying a few key priorities and fashioning them into powerful levers*.

The habits that matter most are the ones that, when they start to shift, dislodge and remake other patterns. For example, a common personal keystone habit for many people is regular exercise. It's common for people who get that right start to sleep and eat better, drink less, etc.

How to create new habits

One of the reasons habits are so powerful is that they create neurological cravings. Most of the time, these cravings emerge so gradually that we're not really aware they exist, so we're often blind to their influence. But as we associate cues with certain rewards, a subconscious craving emerges in our brains that starts the habit loop spinning.

This is how new habits are created: By putting together a cue, a routine, and a reward, and then cultivating a craving that drives the loop. To create a new habit (such as running each morning), **you need to *choose a simple cue*** (e.g. leaving your gym clothes out, lacing your sneakers before breakfast, etc), ***and a clear reward*** (e.g. a midday treat, the satisfaction of completing the run, etc).

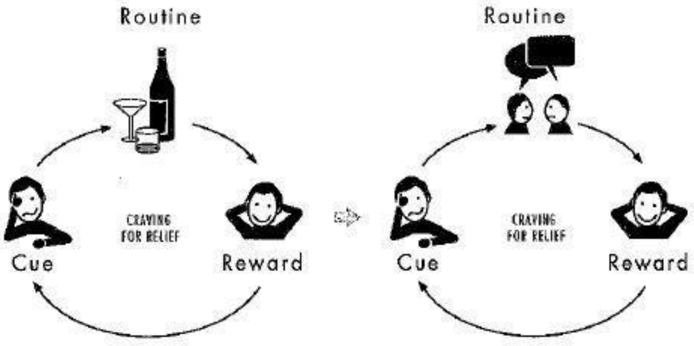
But, studies have shown that a cue and a reward alone aren't enough for a new habit to last. Only when your brain starts expecting the reward - craving the endorphins or sense of accomplishment - will it become automatic to lace up your shoes every morning. The cue, in addition to triggering a routine, must also trigger a craving for the reward to come.

The Golden Rule of habit change

We know that a habit cannot be eradicated. Instead, it must be replaced. Most habits are most malleable when the golden rule is applied:

> ***To change a habit, you must keep the old cue, and deliver the old reward, but insert a new routine.***

Use the same cue. Provide the same reward. Change the routine. Almost any behavior can be transformed if the cue and reward stay the same.



KEEP THE CUE,
PROVIDE THE SAME REWARD,
INSERT A NEW ROUTINE

But this isn’t always enough: For a habit to stay changed, people must believe change is possible. In many cases, this belief only emerges with the help of a group (e.g. Alcoholics Anonymous).

Basically: One way to dramatically increase your odds of success is to commit to changing as part of a group.

How to change your habits

Recap: All habits follow the loop of (A) cue, (B) routine, and (C) reward. To understand your own habits, you need to identify the components of your habit loops. Once you’ve diagnosed the habit loop of a particular behavior, you can look for ways to supplant old vices with new routines.

There are four steps to doing this: a) Identify the routine, b) Experiment with rewards, c) Isolate the cue, and d) Have a plan

Step 1: Identify the (B) routine

With most habits, the routine is the most obvious aspect: It’s the behavior you want to change.

Example: Every afternoon, you go to a cafe and buy a cookie. In this scenario, the routine is that you get up from your desk, walk to the cafe, buy and cookie, and eat it while chatting with friends.

Once you’ve figured out the routine, you must isolate the cue. Hunger? Boredom? Low blood sugar? You need a break? And what’s the reward? The cookie? Change of scenery? Distraction? To figure this out, you need to experiment.

Step 2: Experiment with (C) rewards

Most cravings are obvious in retrospect, but incredibly hard to see when we are under their sway. To figure out which cravings drive particular habits, you can experiment with different rewards. This can take days, weeks, or longer. During this period don’t feel pressure to make lasting change — think of yourself as a scientist collecting data. When you feel the urge to start the routine, adjust it so that it delivers a different reward. For example, instead of going to buy a cookie, go for a walk around the block. The next day, try buying an apple. The next, a cup of coffee, etc. What you choose to do instead of your original reward isn’t important. The point is to test different hypothesis to determine which craving is driving your routine. By experimenting with different rewards, you can isolate what you are actually craving, which is essential in redesigning the habit.

Step 3: Isolate the (A) Cue

The reason why it's so hard to identify cues that trigger our habits is because there is too much information bombarding us as our behaviors unfold. For example, do you eat breakfast at a certain time (1) because you are hungry, (2) because the clock says 7:30, (3) because your family is eating, etc? To identify a cue amid the noise, we can identify categories of behaviors ahead of time to scrutinize in order to see patterns.

Almost all habitual cues fit into one of five categories: 1) Location, 2) Time, 3) Emotional state, 4) Other people, and 5) Immediately preceding action. So, if you're trying to figure out the cue for a habit, write down five things the moment the urge hits: Where are you? What time is it? What's your emotional state? Who else is around? What action preceded the urge?

Step 4: Have a plan

Once you've figured out your habit loop - you've identified the reward driving your behavior, the cue triggering it, and the routine itself - you can start to shift the behavior.

Remember the habit formula: When I see (A) CUE, I will do (B) ROUTINE in order to get (C) REWARD.

To re-engineer the formula, you just need to start making choices again. Break the loop by changing it up. The easiest way to do this is to make a plan. Back to the cookie example: By answering the questions in step 3 for a few days, it became clear that:

The cue is time-based: Roughly 3:30 in the afternoon.

The routine: going to the cafe, buying the cookie, and chatting with friends.

Via experimentation, it was obvious it wasn't actually the cookie that was craved, but the opportunity to socialize. So, a plan to break the loop could look like this: *At 3:30 every day, I will walk to a friend's desk and talk for 10 minutes.* Obviously, changing some habits is more difficult than this, but the framework is a good place to start. Once you understand how a habit operates — once you diagnose the cue, routine and rewards — you gain power over it.

References:

A brief summary of the interesting ideas and concepts from Charles Duhigg's "The Power of Habit"

--- Aidan Hornsby

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BUILDING A BETTER TOMMORROW

It is becoming less practical for many companies to maintain in-house engineering staff. That is where we come in – whenever you need us, either for one-time projects, or for recurring engineering services. We understand the codes and standards, and can offer a range of services related to pressure vessels, tanks and heat exchangers.

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