Corrosion and Materials Professional

API API-571

Version Demo

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QUESTION NO: 1

Regular and controlled carbon grades of stainless steels such as types 304/304H and 316/316H are particularly susceptible to sensitization in the weld HAZ. Low carbon "L" grades are less susceptible and usually can be welded without sensitizing. The "L" grades will not sensitize provided long term operating temperatures do not exceed about __________.

A. 700º F

B. 750º F

C. 800º F

D. 900º F

ANSWER: B

Explanation:

750º F is the correct temperature. API 571 identifies sensitization as precipitation of chromium-rich carbides at grain boundaries in austenitic stainless steels, which can create chromium-depleted zones and make the material susceptible to intergranular corrosion mechanisms, including polythionic-acid stress-corrosion cracking under applicable service conditions. Low-carbon stainless steels are designed with reduced carbon content to limit the amount of carbide precipitation caused by welding and thermal exposure. This makes them substantially more resistant to weld heat-affected-zone sensitization than regular-carbon or high-carbon counterparts.

That benefit has an important long-term temperature limit. For low-carbon "L" grades, sustained operation at approximately **750º F** or below is the commonly cited threshold at which they generally remain protected from sensitization. Time at temperature matters: even a low-carbon alloy can eventually develop damaging carbide precipitation if exposed long enough in the sensitizing range. Therefore, 750º F is used as the practical screening temperature for this API 571 guidance, rather than treating low-carbon grades as universally immune to sensitization. API's corrosion-mechanism guidance is available through its standards publications resources; additional technical background on stainless-steel corrosion is provided by the Nickel Institute technical guides.

QUESTION NO: 2

300 Series SS can suffer pitting corrosion, crevice corrosion and ________ in fresh, blackish and salt water.

A. General corrosion

B. Oxidation

C. SCC

D. None of the above

ANSWER: C

Explanation:

SCC is correct because 300 Series stainless steels are austenitic alloys that can undergo chloride stress-corrosion cracking when tensile stress, a susceptible material condition, and an aqueous chloride-containing environment occur together. Fresh water may contain chlorides through contamination or treatment chemicals, while brackish and salt water inherently provide more significant chloride exposure. Pitting and crevice corrosion can locally damage the normally protective passive film on stainless steel; these localized conditions can help create aggressive chemistry and provide sites from which cracking may initiate when the required tensile stress and temperature conditions are present. In API 571 terminology, this mechanism is generally identified as chloride stress-corrosion cracking of austenitic stainless steels. The expected damage is often branched cracking that may be transgranular or intergranular, and it can lead to leakage or failure with limited overall metal loss. Appropriate material selection, chloride control where practical, temperature management, stress reduction, and inspection for cracking are therefore important for stainless equipment in water service. API's damage-mechanism guidance is available through API Recommended Practice 571; additional technical information on stainless-steel corrosion behavior is available from the International Molybdenum Association.

QUESTION NO: 3

SSC is a form of ________ stress corrosion cracking.

A. Hydrogen

B. Caustic

C. Polythionic

D. Alkaline

ANSWER: A

Explanation:

Hydrogen is correct. Sulfide stress cracking, commonly abbreviated SSC, is a hydrogen-assisted cracking mechanism that affects susceptible high-strength steels and certain other alloys exposed to wet hydrogen sulfide service while under tensile stress. Corrosion reactions in the wet hydrogen sulfide environment generate atomic hydrogen at the metal surface. Hydrogen sulfide interferes with the normal recombination of atomic hydrogen into molecular hydrogen, allowing more atomic hydrogen to enter and diffuse through the metal. In a material with sufficient hardness, susceptible microstructure, and applied or residual tensile stress, the absorbed hydrogen can promote brittle cracking at stresses below those expected for ordinary mechanical failure.

API RP 571 classifies sulfide stress cracking among the damage mechanisms associated with wet hydrogen sulfide environments and describes its hydrogen-related nature. The term is also used consistently in the materials requirements of NACE MR0175/ISO 15156, which addresses resistance of metallic materials to cracking in hydrogen sulfide-containing environments in oil and gas production. Therefore, the appropriate completion is “Hydrogen,” expressing that SSC is a form of hydrogen stress cracking. See API RP 571 information and AMPP NACE MR0175/ISO 15156.

QUESTION NO: 4

There is currently no known metal alloy that is immune to _________ under all conditions.

A. Carburization

B. Metal dusting

C. Decarburization

D. None of the above

ANSWER: B

Explanation:

Metal dusting is correct. API RP 571 identifies metal dusting as a high-temperature form of carburization that occurs in strongly carburizing process environments, generally at temperatures of about 400–850°C (750–1560°F). Carbon deposits at the metal surface and penetrates the alloy; the alloy can progressively disintegrate into fine metal particles, carbides, graphite, and coke-like material. Resistance depends on alloy composition, temperature, gas chemistry, carbon activity, surface condition, and the stability of protective oxide films. Although high-chromium and nickel-containing alloys can offer substantially improved resistance in particular services, their protection can be defeated when the process environment permits carbon transfer through or disruption of the surface oxide. Consequently, no currently known metallic alloy is immune to metal dusting in every possible operating condition. Materials selection must therefore be coupled with control of the carburizing environment, operating temperature, and inspection strategy. API RP 571 is the principal API reference for recognizing this and other damage mechanisms in refinery and petrochemical equipment; see API RP 571. Additional technical resources on materials degradation and corrosion mechanisms are available from AMPP.

QUESTION NO: 5

Vibration-induced fatigue can be eliminated or reduced through _________ and the use of supports and vibration dampening equipment. Material upgrades are not usually a solution.

A. Hangers

B. Dummy legs

C. Design

D. None of the above

ANSWER: C

Explanation:

Design is correct because vibration-induced fatigue is fundamentally controlled by reducing cyclic stresses, resonant response, and displacement in the piping or equipment configuration. Effective design measures can include changing geometry to eliminate stress concentrators, increasing stiffness, revising span lengths, relocating attachments, providing adequate restraint, and avoiding natural frequencies that can be excited by rotating or pulsating machinery. These actions address the mechanical conditions that produce repeated stress cycles and fatigue cracking. Supports and damping equipment complement sound design by limiting movement and dissipating vibration energy, particularly near small-bore connections, branch connections, unsupported piping, and locations adjacent to pumps, compressors, and control valves. API's damage-mechanism guidance identifies vibration-induced fatigue as a mechanical-fatigue mechanism and emphasizes managing vibration and system configuration rather than relying on a change to a stronger material. A material upgrade alone generally does not remove the cyclic loading or resonance responsible for fatigue damage. See the API publication listing for API Recommended Practice 571 and API's standards program for the governing damage-mechanism and inspection guidance.

QUESTION NO: 6

The primary factors affecting high temperature oxidation are metal temperature and _______.

A. Pressure

B. Alloy composition

C. Stress

D. Oxygen

ANSWER: B

Explanation:

Alloy composition is correct because high-temperature oxidation resistance depends fundamentally on both the metal temperature and the material's chemical composition. As temperature rises, oxidation reactions and diffusion processes generally accelerate, influencing the rate at which scale forms and grows on a component's surface. Alloy composition determines whether the metal can form a stable, slow-growing, adherent protective oxide scale under the applicable service conditions. In particular, alloys containing sufficient chromium, aluminum, or silicon can develop protective oxide films that substantially limit further reaction between the base metal and the oxidizing environment. The effectiveness, continuity, and stability of those scales are therefore material-specific and can change significantly with alloy grade and temperature. API 571 identifies high-temperature oxidation as metal loss caused by reaction with oxygen at elevated temperature and identifies metal temperature and alloy composition as the primary influencing factors. This relationship is essential when selecting materials for fired heaters, furnaces, hot process piping, and other equipment exposed to elevated-temperature oxidizing service. See the American Petroleum Institute standards resources and the API Publications Store for API 571 publication information.

QUESTION NO: 7

________ significantly increases the probability and severity of blistering, HIC and SOHIC damage.

A. Caustic

B. Cyanides

C. Stress

D. Temperature

ANSWER: B

Explanation:

Cyanides is correct because cyanide compounds are recognized accelerants of wet hydrogen sulfide damage in susceptible steels. In aqueous sour-service environments, hydrogen generated by the corrosion reaction can enter steel rather than recombine harmlessly at the surface. Cyanides interfere with hydrogen recombination and thereby increase the amount of atomic hydrogen available for absorption into the metal. The resulting hydrogen accumulation at inclusions, laminations, and other trapping sites can produce internal cracking and blistering. Where the material is stressed, including in heat-affected zones or highly stressed regions, this increased hydrogen charging also raises susceptibility to hydrogen-induced cracking and stress-oriented hydrogen-induced cracking. API 571 identifies the presence of cyanides as a factor that significantly increases both the likelihood and severity of blistering, HIC, and SOHIC in wet H_2S service. This is important when assessing sour-water systems and process streams that may contain cyanide species, since their presence materially changes the anticipated damage risk and the need for suitable materials, fabrication controls, and inspection planning. See API Recommended Practice 571 information and API RP 571 in the API Webstore.

QUESTION NO: 8

Which damage mechanism may occur when carbon steel is exposed to elevated temperatures in a hydrogen-rich environment and methane forms within the steel?

A. High temperature hydrogen attack

B. Hydrogen blistering

C. Chloride stress corrosion cracking

D. Galvanic corrosion

ANSWER: A

Explanation:

High temperature hydrogen attack is correct. At elevated temperature and hydrogen partial pressure, hydrogen can diffuse into susceptible carbon and low-alloy steels and react with carbon in the steel to form methane. Because methane cannot readily diffuse through the metal, it can accumulate at grain boundaries or other internal locations, causing fissuring, decarburization, loss of strength, and progressive internal damage.

HTHA is distinct from wet-H_2S hydrogen damage, which occurs in aqueous sour environments and involves different mechanisms. Screening for HTHA requires consideration of material, temperature, hydrogen partial pressure, exposure time, fabrication history, and operating excursions. API RP 941 provides established guidance for evaluating materials in elevated-temperature hydrogen service, while API 571 describes the mechanism and its inspection implications. See API RP 941 and API RP 571.

QUESTION NO: 9

Type 304L SS is satisfactory for phosphoric acid concentration of 100% up to about _________. Type 321 is required from there to 225º F.

A. 140º F

B. 150º F

C. 100º F

D. 120º F

ANSWER: D

Explanation:

120º F is correct. API 571's discussion of phosphoric-acid corrosion provides material-selection guidance based on acid concentration, temperature, impurities, and oxidizing conditions. For nominally pure, 100 percent phosphoric acid, Type 304L stainless steel is regarded as satisfactory only up to approximately 120º F. At temperatures above that point, increasing corrosion susceptibility requires the improved resistance associated with stabilized Type 321 stainless steel, which is identified for service up to about 225º F under the stated conditions.

This temperature transition is a practical corrosion-control limit rather than merely a mechanical-design temperature. Phosphoric-acid service must be evaluated carefully because contaminants such as fluorides, chlorides, sulfuric acid, and reducing species can materially increase corrosivity and may invalidate guidance intended for pure acid. The stated answer therefore matches the specific concentration and material-temperature range given in the question. API 571 is the industry reference for identifying damage mechanisms and considering corrosion-related material limits; its current publication information is available from the American Petroleum Institute. Additional industry corrosion resources are available through AMPP.

QUESTION NO: 10

How can temper embrittlement be prevented if a material contains critical levels of the appropriate impurity elements and is exposed in the embrittling temperature range?

A. Use of a controlled pressurization sequence

B. Postweld heat treatment (PWHT) of repairs

C. Specification of Charpy V-notch impact test

D. Embrittlement cannot be prevented

ANSWER: D

Explanation:

Embrittlement cannot be prevented is correct under the conditions stated. Temper embrittlement is a reversible loss of toughness that occurs in susceptible low-alloy steels after exposure to the approximate 650 °F to 1,070 °F (343 °C to 577 °C) temperature range. Susceptibility is primarily controlled by the steel's composition, particularly residual impurity elements such as phosphorus, tin, antimony, and arsenic, and by alloying-element effects. Once a material has impurity levels that make it susceptible and it spends sufficient time in the embrittling range, impurity segregation at prior-austenite grain boundaries can occur; consequently, the embrittlement mechanism cannot be prevented merely through operational controls during that exposure.

API RP 571 addresses temper embrittlement as a metallurgical degradation mechanism and emphasizes material selection, chemistry control, and toughness assessment as the practical means of managing susceptibility and brittle-fracture risk. In particular, low transition-temperature or impact-toughness requirements help ensure acceptable toughness for anticipated service, but they do not stop impurity segregation after susceptible material is exposed. In some cases, a de-embrittlement heat treatment followed by sufficiently rapid cooling may restore toughness, although later exposure in the susceptible temperature range can cause embrittlement again. See API RP 571 and API Standards.

QUESTION NO: 11

Permanent deformation occurring at relatively low stress levels as a result of localized overheating is called ________.

A. Stress cracking

B. Brittle fracture

C. Temper embrittlement

D. Stress rupture

ANSWER: D

Explanation:

Stress rupture is correct because it describes failure resulting from time-dependent deformation at elevated temperature under sustained stress, including stresses that may be below the material's yield strength at room temperature. Localized overheating can raise a portion of equipment, such as a furnace tube, heater coil, or pressure boundary, into the creep temperature range. In that overheated area, the metal progressively strains, commonly producing localized bulging or thinning. Continued deformation damages the material's microstructure, reduces its remaining load-carrying capability, and can ultimately culminate in rupture.

In the API damage-mechanism framework, creep and stress rupture are associated with prolonged exposure to elevated temperatures and applied stress. The important feature in this question is the combination of permanent, localized deformation and overheating while under load: these conditions identify the progression toward stress rupture. API's API Recommended Practice 571 addresses creep and stress rupture as damage mechanisms for fixed equipment. Additional technical background on high-temperature creep behavior is available from the TWI creep overview.

QUESTION NO: 12

Hydrogen permeation or diffusion rates have been found to be minimal at pH _______ and increase at both higher and lower pH's.

A. 4

B. 5

C. 6

D. 7

ANSWER: D

Explanation:

7 is correct. API RP 571 describes hydrogen permeation/diffusion behavior in aqueous corrosion service as having a minimum around neutral pH, approximately pH 7, with rates increasing on either the acidic or alkaline side. This relationship matters because atomic hydrogen generated at a metal surface can enter the steel rather than recombine to molecular hydrogen and escape. Once absorbed, hydrogen may diffuse through the material and can contribute to damage mechanisms when susceptible material, stresses, and operating conditions are present.

At near-neutral pH, the surface electrochemical conditions result in the lowest observed permeation rate in the relationship cited by API 571. Moving below neutral pH increases the tendency for hydrogen evolution associated with acidic corrosion reactions. Moving above neutral pH can also increase permeation under applicable alkaline electrochemical conditions. Therefore, the stated minimum is not simply a generic "low-corrosion" condition; it is the specific pH-dependent permeation trend documented for hydrogen-related corrosion and damage assessment.

For the governing industry guidance, consult API Recommended Practice 571, Damage Mechanisms Affecting Fixed Equipment in the Refining Industry. Additional technical context on hydrogen damage mechanisms is available from AMPP's hydrogen embrittlement resources.

QUESTION NO: 13

Creep damage is found in high temperature equipment operating above the ________. Fired heater tubes and components, Catalytic reactors, FCC reactors and FCC fractionator and regenerator internals all operate in or near this.

A. Transition range

B. MADT

C. Creep range

D. None of the above

ANSWER: C

Explanation:

Creep range is correct because creep is a time-dependent, permanent deformation mechanism that becomes a relevant damage concern when metal components operate at elevated temperature for sustained periods. In refinery and petrochemical service, the applicable temperature is not a single universal value: it depends on the alloy, its metallurgical condition, stress level, and operating duration. The creep range identifies the elevated-temperature regime in which creep deformation, creep rupture, and related damage such as stress relaxation may accumulate and therefore require consideration in design, inspection planning, remaining-life assessment, and fitness-for-service evaluations.

Fired-heater tubes, reactor internals, and fluid catalytic cracking equipment commonly see temperatures and exposure durations that place their materials in, or close to, this regime. The important engineering temperature is the component's actual metal temperature rather than simply the process-fluid temperature, since tube-wall temperatures and localized hot areas can govern creep susceptibility. API 571 identifies creep and stress rupture as high-temperature damage mechanisms and describes the affected equipment and materials. The API publication listing is available at API RP 571. For assessment of components affected by creep damage, API's fitness-for-service standard is available at API 579-1/ASME FFS-1.

QUESTION NO: 14

____________ is a form of environmental cracking that can initiate on the surface of high strength low alloy steels and carbon steels with highly localized zones of high hardness in the weld metal and HAZ as a result of exposure to aqueous HF acid service.

A. Sulfide stress cracking

B. Hydrogen stress cracking

C. Caustic stress cracking

D. Hydrogen induced cracking

ANSWER: B

Explanation:

Hydrogen stress cracking is correct because aqueous hydrofluoric-acid service can generate atomic hydrogen at the steel surface during corrosion. That hydrogen can enter susceptible carbon steels and high-strength low-alloy steels. Cracking is most likely where welding has created a hard, highly stressed, and relatively brittle local microstructure, including weld metal and the heat-affected region. The combination of absorbed hydrogen, tensile stress, and high hardness provides the conditions for delayed hydrogen-assisted cracking, which is the basis for identifying this damage mechanism as hydrogen stress cracking in hydrofluoric-acid service.

API 571 describes hydrogen stress cracking as an environmental cracking mechanism associated with exposure to aqueous hydrofluoric acid and emphasizes susceptibility in high-strength materials and localized hard weld areas. Appropriate prevention therefore centers on material-strength and hardness control, qualified welding procedures, and consideration of postweld heat treatment where applicable, so that the welded region does not retain a susceptible hard microstructure. The API publication listing is available from API 571. General technical information on hydrofluoric acid hazards and its reactive nature is also available from NIOSH.

QUESTION NO: 15

All piping and equipment exposed to HF acid at any concentration with hardness levels above ________ are subject to hydrogen stress cracking.

A. 200 BHN

B. 210 BHN

C. 227 BHN

D. 237 BHN

ANSWER: D

Explanation:

237 BHN is the applicable hardness threshold for this API 571 hydrogen stress cracking guidance for carbon and low-alloy steel equipment in hydrofluoric acid service. HF corrosion reactions can generate atomic hydrogen at the steel surface. When hydrogen enters a susceptible material under tensile stress, it can promote cracking, particularly at weldments, heat-affected zones, cold-worked areas, and other locally stressed regions. Hardness is an important practical indicator of susceptibility because harder microstructures generally have reduced resistance to hydrogen-assisted cracking. API 571 identifies steel with hardness above 237 Brinell hardness number as subject to hydrogen stress cracking when exposed to HF acid at any concentration. Therefore, maintaining hardness at or below this limit is a key materials, fabrication, welding, and inspection control for HF alkylation and other HF-containing services. The threshold should be applied with suitable hardness testing and attention to local hard zones rather than relying solely on nominal base-material properties. API's corrosion-mechanism guidance is published as API 571, while HF-service integrity practices are addressed in API recommended practices for HF alkylation units. See the API standards program and API's standards publications and announcements for current document availability and editions.

QUESTION NO: 16

(Chloride stress corrosion cracking of 300 series stainless steel initially becomes a concern at a metal temperature above:)

A. 100 °F (38 °C)

B. 140 °F (60 °C)

C. 180 °F (82 °C)

D. 212 °F (100 °C)

ANSWER: B

Explanation:

140 °F (60 °C) is the appropriate initial screening temperature for chloride stress corrosion cracking of 300-series austenitic stainless steels. API RP 571 identifies chloride stress corrosion cracking as a damage mechanism that requires a susceptible material, tensile stress, an aqueous chloride-containing environment, and sufficiently elevated metal temperature. Although actual cracking susceptibility depends on chloride concentration, pH, oxygen availability, wetting/drying conditions, stress level, alloy composition, and time of exposure, the risk becomes a recognized concern when metal temperature exceeds about 140 °F (60 °C). This threshold is used as a practical inspection and materials-selection screening criterion, rather than as an absolute temperature below which cracking cannot occur. In service, insulation-related water ingress, process leaks, and chloride contamination can create concentrated chloride solutions on external or internal stainless-steel surfaces. As temperature rises above this range, evaporation and concentration of chlorides can substantially increase the likelihood of cracking under tensile stress. API RP 571 describes the applicable damage mechanism, susceptible materials, critical environmental conditions, and expected forms of damage in its discussion of chloride stress corrosion cracking. See the API RP 571 standard information and API's publications catalog for the current controlled edition and related materials.

QUESTION NO: 17

The level of creep damage is a function of the material and the coincident _________ level at which the creep deformation occurs.

A. Pressure/Temperature

B. Pressure/Stress

C. Temperature/Stress

D. None of the above

ANSWER: C

Explanation:

Temperature/Stress is correct. Creep is time-dependent permanent deformation that occurs when a material is exposed to elevated temperature while under sustained stress. The amount and rate of damage depend on the specific material's high-temperature properties and on the simultaneous temperature and stress conditions. Higher temperatures increase atomic mobility and make creep mechanisms more active, while sustained stress supplies the driving force for deformation, cavity formation, and eventual cracking or rupture. Accordingly, creep assessment cannot be based on temperature alone or stress alone; the coincident temperature/stress level and duration of exposure are essential inputs for evaluating remaining life and susceptibility to creep damage. API RP 571 identifies creep and stress rupture as a damage mechanism associated with prolonged exposure to high temperatures and stresses, with damage typically developing progressively over time. Further technical background on creep behavior and rupture testing is provided by API RP 571 information and ASTM E139, creep and stress-rupture testing.

QUESTION NO: 18

(Repeated) The best method for finding damage from sigma phase embrittlement is:

A. Hardness testing

B. Ductility testing

C. Magnetic particle testing

D. Metallographic testing

ANSWER: D

Explanation:

Metallographic testing is the best method for finding damage from sigma phase embrittlement because sigma phase is a chromium- and molybdenum-rich intermetallic constituent that forms within the microstructure of susceptible stainless steels and high-alloy materials after exposure to an appropriate elevated-temperature range. Its presence, distribution, and morphology are established most directly by examining a properly prepared and etched material sample under microscopy. Metallography can reveal sigma-phase precipitation in ferrite or along microstructural features and permits the examiner to relate the observed phase transformation to the material's embrittlement condition. This is especially important because the damage mechanism is fundamentally a loss of toughness and ductility caused by a microstructural change, rather than merely a visible surface condition. API 571 identifies sigma phase embrittlement as a damage mechanism affecting relevant alloy systems and provides the damage-mechanism context used in refinery inspection and materials evaluations. Standard metallographic preparation and etching practices support reliable microscopic examination of the affected alloy. See the API 571 information page and ASTM's E407 guide for microetching metals and alloys.

QUESTION NO: 19

Thermal fatigue cracks propagate ________ to the stress and are usually dagger shaped, transgranular and oxide-filled.

A. Axial

B. Diagonal

C. Transverse

D. Angular

ANSWER: C

Explanation:

Transverse is correct because thermal-fatigue cracking is driven by cyclic thermal stresses created when temperature changes are constrained by geometry, attachments, differing wall thicknesses, or uneven heating and cooling. A fatigue crack opens and advances on the plane subject to the cyclic tensile stress; consequently, its visible crack path is transverse (perpendicular) to the principal tensile stress direction. In process equipment and piping, repeated thermal expansion and contraction can produce localized alternating stresses that initiate cracks at stress concentrators, such as weld details, nozzles, mixing points, and areas exposed to thermal cycling. API 571 identifies thermal fatigue as a relevant damage mechanism and describes its characteristic cracking morphology, including transgranular cracking that may be oxide-filled when elevated-temperature cycling occurs. The dagger-shaped appearance can result from the crack's growth through the component wall under the thermal-stress pattern. Correctly associating a transverse crack orientation with the acting tensile stress is important during inspection because it helps inspectors relate the observed crack geometry to thermal cycling and identify the source of restraint or temperature differential that must be addressed. See the API 571 damage-mechanisms standard information and the TWI thermal-fatigue overview.

QUESTION NO: 20

Corrosion from oxygen in boiler feed water usually creates:

A. Uniform corrosion.

B. Isolated pitting.

C. Intergranular cracking.

D. Transgranular cracking.

E. Hard and brittle zones.

ANSWER: B

Explanation:

Isolated pitting is correct. Dissolved oxygen in boiler feedwater is a strong cathodic depolarizer and can cause highly localized attack on carbon-steel feedwater-system components. The electrochemical reaction is often concentrated at discrete surface sites, particularly where oxygen reaches the metal through deposits, at surface imperfections, or in areas with disturbed protective oxide films. This produces pits rather than a predictable, even loss of wall thickness. In boilers and associated feedwater equipment, oxygen pitting can be severe because the small anodic areas within individual pits support an aggressive localized corrosion cell, while the surrounding surface acts as a relatively large cathodic area. The resulting pits may deepen rapidly and can lead to leakage or tube failure even when overall metal loss appears minor. Effective control therefore focuses on limiting oxygen entry through mechanical deaeration, maintaining appropriate chemical oxygen-scavenger treatment where applicable, and preventing air ingress during operation and shutdown. API 571 identifies oxygen-related water corrosion as localized pitting in relevant aqueous-service damage mechanisms. See API RP 571 and the U.S. Department of Energy's Boiler and Feedwater Systems guidance.

QUESTION NO: 21

Ammonium chloride salts may be whitish, greenish or _________.

A. Reddish

B. Brownish

C. Yellowish

D. Bluish

ANSWER: B

Explanation:

Brownish is correct. In the ammonium chloride corrosion mechanism described by API 571, deposited ammonium chloride salts can have a whitish appearance, but field deposits may also appear greenish or brownish. The variation in observed color is important during visual inspection because these deposits form where ammonia and hydrogen chloride combine, typically as process streams cool below the salt-deposition temperature. The deposits are hygroscopic, meaning they readily absorb water. Once wetted, they can create a concentrated, acidic chloride-containing electrolyte at the metal surface and cause aggressive localized corrosion, frequently in overhead-system or related piping environments. Therefore, a brownish deposit does not rule out ammonium chloride salt deposition; inspectors should consider the process chemistry, deposit location, water availability, and evidence of localized metal loss when evaluating such findings. API 571 provides the industry damage-mechanism guidance for recognizing ammonium chloride corrosion and assessing the associated inspection concerns. See API 571—Damage Mechanisms Affecting Fixed Equipment in the Refining Industry and API's Standards catalog for the governing publication and related inspection guidance.

QUESTION NO: 22

Temper embrittlement can be identified by a(n) shift in the ductile-to-brittle transition temperature measured in a Charpy impact test.

A. Upward

B. Downward

C. Abrupt

D. None of the above

ANSWER: A

Explanation:

Upward is correct. Temper embrittlement is a loss of toughness in susceptible low-alloy steels that have spent time within, or been slowly cooled through, an intermediate temperature range. The degradation is commonly associated with segregation of impurity elements such as phosphorus, tin, antimony, and arsenic to prior-austenite grain boundaries. Although strength and room-temperature tensile properties may show little change, the material becomes more susceptible to brittle fracture at temperatures where it previously exhibited ductile behavior.

Charpy V-notch impact testing characterizes this change by developing an impact-energy-versus-temperature transition curve. When temper embrittlement is present, the ductile-to-brittle transition temperature moves to a higher temperature—an upward shift. Consequently, at a given temperature in the transition region, the embrittled material absorbs less impact energy and may fail in a more brittle manner. API 571 identifies temper embrittlement as a damage mechanism affecting certain steels and recognizes impact testing and transition-temperature behavior as important considerations for evaluating fracture resistance. See API Recommended Practice 571 and the TWI overview of temper embrittlement.

QUESTION NO: 23

_________ is the sudden rapid fracture under stress (residual or applied) where the material exhibits little or no evidence of ductility or plastic deformation.

A. Thermal fatigue

B. Thermal shock

C. Brittle fracture

D. Stress fracture

ANSWER: C

Explanation:

Brittle fracture is correct because it is the failure mode characterized by sudden, rapid cracking under applied or residual stress with little or no macroscopic plastic deformation. Rather than undergoing appreciable yielding or visible distortion before failure, a susceptible material can fracture abruptly once the local stress intensity exceeds its resistance to crack propagation. This behavior is especially important for pressure-containing equipment because carbon and low-alloy steels may lose fracture toughness at lower temperatures, in the presence of high constraint, at notches or flaws, and in conditions involving residual welding stresses. API 571 addresses brittle fracture as a damage mechanism and identifies the relevance of material toughness, operating temperature, stress state, fabrication details, and pre-existing discontinuities when evaluating susceptibility. The wording in the question directly reflects the defining feature of brittle fracture: rapid failure with minimal evidence of ductility or plastic flow. Inspection and integrity assessments therefore focus on identifying crack-like flaws, confirming appropriate materials and minimum pressurization temperatures, and managing operating conditions that could place equipment in a brittle-fracture-susceptible regime. See the API 571 standard information at API Standard 571 and API's mechanical-integrity resources at API Standards.

QUESTION NO: 24

____________ is often found in piping and equipment that handles caustic, including H^2S and mercaptan removal units, as well as equipment that uses caustic for neutralization in sulfuric acid and HF acid units.

A. Carburization

B. Sulfide corrosion

C. Caustic embrittlement

D. Hydrogen cracking

ANSWER: C

Explanation:

Caustic embrittlement is correct because it is the traditional term for caustic stress corrosion cracking of susceptible carbon steels and low-alloy steels exposed to aqueous sodium hydroxide solutions while under tensile stress. API RP 571 describes this damage mechanism as occurring in equipment that handles caustic, including process piping and vessels in refinery services. The stated applications are especially characteristic: caustic is commonly used in hydrogen sulfide and mercaptan-removal systems, and it may be used for neutralization in sulfuric-acid and hydrofluoric-acid alkylation-related services. Damage is promoted when caustic concentration and metal temperature are sufficiently high, particularly at locations where caustic can concentrate through evaporation, leakage, or poor flushing. Weld residual stress, cold work, and applied loading provide the tensile stresses needed for cracking. Cracks are often branched and can develop adjacent to welds, at heat-affected zones, and around nozzles or other stress concentrators. The terminology "caustic embrittlement" remains widely used in inspection and damage-mechanism discussions, although "caustic stress corrosion cracking" more precisely identifies the cracking mechanism. See the API catalog entry for API RP 571 and the OSHA sodium hydroxide safety data information.

QUESTION NO: 25

Which of the following materials are susceptible to nitriding?

A. Carbon steel

B. 300 Series SS

C. 400 Series SS

D. All of the above

ANSWER: D

Explanation:

All of the above is correct. API RP 571 identifies carbon and low-alloy steels, 300 Series stainless steels, and 400 Series stainless steels among the materials affected by nitriding. This damage mechanism results from exposure to nitrogen-containing environments at elevated temperatures, especially ammonia-bearing process streams. Nitrogen diffuses into the metal surface and reacts with alloying elements to form hard nitride phases. The resulting nitrided layer may be substantially harder but can have reduced ductility and toughness, making it susceptible to cracking or brittle damage when stressed, thermally cycled, or mechanically worked.

Material response varies with alloy composition, temperature, nitrogen activity, exposure duration, and surface condition; nevertheless, each material family listed can be affected under relevant service conditions. Inspection planning should therefore consider process areas involving ammonia or other nitrogen-containing compounds, with attention to locations exposed to elevated temperatures and to evidence of surface hardening, cracking, or loss of mechanical integrity. API RP 571 is the industry reference for recognizing this and other fixed-equipment damage mechanisms; see the API RP 571 standard information and the API Webstore listing for API RP 571.

QUESTION NO: 26

Temperature, ________ and stress are critical factors of stress rupture. This is usually found in furnaces with coking tendencies and fired heater tubes.

A. Pressure

B. Ductility

C. Time

D. Tensile strength

ANSWER: C

Explanation:

Time is correct because stress rupture is a time-dependent high-temperature damage mechanism. API 571 describes stress rupture as the result of exposure to stress at elevated temperatures for an extended period, producing creep deformation and ultimately cracking or rupture. The combined effect of metal temperature, sustained applied stress, and duration of exposure governs the accumulation of creep damage and the remaining rupture life of the component. In fired heater tubes and furnace services subject to coking, deposits can restrict heat transfer from the tube wall to the process fluid. This causes the tube metal temperature to rise above its intended operating temperature. If that elevated temperature persists while the tube remains under pressure-induced hoop stress, creep damage can progressively accumulate over time, potentially causing bulging, thinning, fissuring, and eventual stress rupture. Time is therefore essential: a short temperature excursion may not produce the same damage as prolonged operation at an elevated tube-metal temperature. This relationship is commonly evaluated through creep-rupture data and time-temperature parameters, such as the Larson-Miller parameter, which relate stress, temperature, and time to expected rupture behavior. See API's API RP 571 information and the TWI overview of creep.

QUESTION NO: 27

Mechanical fatigue is caused by:

A. Cyclic stresses occurring over a long period of time.

B. Higher than average stresses at high temperatures.

C. Constant stresses occurring at low temperatures.

D. Cyclic operating conditions of bird poop then rain, bird poop then rain, etc.

ANSWER: A

Explanation:

Mechanical fatigue is caused by cyclic stresses occurring over a long period of time. Fatigue damage develops when a component experiences repeated loading and unloading, pressure or temperature fluctuations, vibration, rotating-equipment loads, or other stress reversals. Although the stress in an individual cycle may be below the material's yield strength, repeated cycles can initiate very small cracks at stress concentrators such as weld toes, attachments, notches, thread roots, or geometric discontinuities. Continued cycling propagates those cracks until the remaining uncracked section can no longer support the applied load, potentially resulting in a sudden fracture.

In API 571 terminology, mechanical fatigue is a cracking damage mechanism associated with cyclic mechanical loading. Assessing it therefore requires identifying credible cycle sources, their magnitude and frequency, local stress concentration effects, and the number of cycles accumulated during service. The phrase "over a long period of time" appropriately captures the cumulative nature of fatigue, though fatigue can also occur in relatively short service periods when cycling is frequent or stresses are high. API identifies fatigue among the damage mechanisms addressed for fixed equipment in refining and petrochemical service; see the API 571 standard information. Further background on cyclic loading and fatigue failure is available from Encyclopaedia Britannica's fatigue overview.

QUESTION NO: 28

________ has been a major problem on coke drum shells.

A. Thermal fatigue

B. Stress cracking

C. Erosion

D. Temper embrittlement

ANSWER: A

Explanation:

Thermal fatigue has been a major problem on coke drum shells because delayed-coking service repeatedly subjects the shell, skirt, nozzles, and attachment areas to large temperature changes during filling, steaming, quenching, cooling, and decoking cycles. These recurring thermal transients create cyclic thermal stresses when different portions of the vessel heat or cool at different rates or are locally restrained from expanding and contracting. Over many operating cycles, the stress reversals can initiate fatigue cracks at locations with geometric discontinuities, weld details, and areas of high thermal gradient. This mechanism is especially significant for coke drums because the cyclic nature of their operation differs substantially from steady, continuously operated pressure vessels. Effective integrity management therefore requires attention to operating-cycle severity, temperature monitoring, inspection for cracking in susceptible areas, and assessment methods appropriate to fatigue damage. API 571 identifies thermal fatigue as a damage mechanism associated with cyclic temperature changes and provides the damage-mechanism framework used in refinery equipment assessment. The API delayed-coker guidance also recognizes the demanding cyclic service experienced by coke drums. See API Recommended Practice 571 information and API coke-drum guidance information.

QUESTION NO: 29

Carbonate stress corrosion cracking usually occurs at welds or cold worked areas that __________.

A. Have been stressed relieved

B. Have not been stressed relieved

C. Have high residual stress

D. Have high-applied stress

ANSWER: C

Explanation:

Carbonate stress corrosion cracking usually occurs at welds or cold-worked areas that **have high residual stress**. This damage mechanism affects carbon steel in aqueous carbonate or bicarbonate process environments, particularly where conditions promote concentration of carbonate salts. Like other forms of stress corrosion cracking, it requires the simultaneous presence of a susceptible material, a cracking environment, and tensile stress. Weld fabrication creates localized, locked-in tensile residual stresses in the heat-affected zone and adjacent base metal; cold forming can similarly leave substantial residual tensile stress. These localized stresses provide the mechanical driving force for crack initiation and propagation even when the component is not subject to an unusually high externally applied load. API 571 identifies welds and cold-worked locations as typical susceptible sites because of these high residual stresses. Appropriate postweld heat treatment or stress-relief treatment can reduce residual tensile stress where it is suitable for the equipment, materials, and service conditions, thereby reducing susceptibility. The API 571 damage-mechanism guidance is available through the API 571 standard information page. Additional corrosion-engineering background on stress corrosion cracking is provided by AMPP's stress corrosion cracking overview.

QUESTION NO: 30

Naphthenic acid corrosion is most severe in _________ flow; in areas of high velocity or turbulence and in distillation towers where hot vapors condense to form liquid phase droplets.

A. Single phase

B. Two phase

C. Three phase

D. Negative phase

ANSWER: B

Explanation:

Two phase is correct. API RP 571 describes naphthenic acid corrosion (NAC) as a high-temperature corrosion mechanism associated with crude oils containing naphthenic acids, commonly affecting refinery piping and equipment at elevated temperatures. The mechanism is especially aggressive where a hydrocarbon vapor and liquid coexist. In two-phase service, condensing liquid droplets and turbulent vapor/liquid flow continually contact metal surfaces, disrupt protective corrosion-product films, and increase mass transfer of corrosive acids to the surface. This produces the localized, often severe wall thinning characteristic of NAC in high-velocity locations such as transfer lines, elbows, reducers, furnace outlet circuits, and areas of distillation equipment where hot vapors condense. The wording in the question directly reflects this important API 571 susceptibility condition: high velocity or turbulence combined with vapor-to-liquid condensation creates a particularly damaging two-phase environment. Material selection, process conditions, velocity, acid content, and sulfur content all influence the actual corrosion rate, but identifying two-phase flow is central to recognizing the highest-risk locations during inspection planning. See the API listing for API RP 571, Damage Mechanisms Affecting Fixed Equipment in the Refining Industry and AMPP's overview of corrosion mechanisms.

QUESTION NO: 31

Caustic embrittlement is a form of stress corrosion cracking characterized by surface-initiated cracks that occur in piping and equipment exposed to caustic, primarily adjacent to non-PWHT welds. Which of the following materials is the most resistant to embrittlement?

A. Carbon steel

B. Nickel based alloys

C. Low alloy steels

D. 400 Series SS

ANSWER: B

Explanation:

Nickel based alloys are the most resistant choice because nickel has strong resistance to stress-corrosion cracking in caustic (sodium hydroxide) service. Caustic embrittlement requires the combined effects of a susceptible material, tensile stress, and a sufficiently concentrated and hot caustic environment. Weldments can be particularly vulnerable because welding may leave high residual tensile stresses if postweld heat treatment is not applied. Nickel-based alloys retain a protective, stable corrosion-resistant surface in alkaline environments and are widely selected where process conditions make caustic cracking a credible damage mechanism. Their resistance is especially valuable for equipment operating at elevated temperature or in concentrated caustic solutions, where material selection must account for both general corrosion and environmentally assisted cracking. API 571 identifies caustic embrittlement as a damage mechanism affecting refinery pressure equipment and emphasizes the importance of material, temperature, caustic concentration, and stress in assessing susceptibility. The API standard can be accessed through API Recommended Practice 571 information. Additional technical background on nickel alloys in caustic environments is available from Nickel Institute technical guides.

QUESTION NO: 32

Soil to Air interface areas are usually more susceptible to corrosion than the rest of the structure because of ___________ and __________ availability.

A. Moisture

B. Bacteria

C. Oxygen

D. B and C

E. A and C

ANSWER: E

Explanation:

The correct completion is the combined availability of moisture and oxygen. The soil-to-air interface is a transition zone that commonly experiences alternating wetting and drying. Moisture retained in the soil or deposited near grade provides the electrolyte required for electrochemical corrosion, while exposure to air supplies oxygen for the cathodic reaction. The availability of these two essentials is often uneven along the metal surface: the section near or just above grade can be better oxygenated than the continuously buried section, creating a differential-aeration corrosion cell. This concentration-cell effect can make corrosion particularly localized and severe around the grade line, even where the remainder of the buried or atmospheric portion has less aggressive conditions. API 571 identifies corrosion mechanisms and the environmental factors that influence their occurrence, including aqueous and atmospheric conditions relevant to such interfaces. Corrosion fundamentals likewise recognize water/electrolyte and oxygen availability as key drivers of common electrochemical corrosion processes. See the API 571 standard information page and AMPP's corrosion overview.

QUESTION NO: 33

Short-term stress rupture is a/an:

A. failure caused by repeated cycling from elevated temperature, typically characterized by through-wall oxide filled ruptures with little bulging.

B. elevated temperature failure caused by localized overheating, typically characterized by bulging and thinning.

C. elevated temperature failure caused by diffusion of hydrogen into the material, typically characterized by blistering and cracking.

D. cracking failure caused by sulfides formed at elevated temperature that convert to acids on exposure to moisture and oxygen.

ANSWER: B

Explanation:

“elevated temperature failure caused by localized overheating, typically characterized by bulging and thinning” is correct. API RP 571 describes creep and stress-rupture damage as occurring when a component operates under sustained stress at elevated temperature. Short-term stress rupture is associated with a significant, localized temperature excursion, such as flame impingement, loss of flow, poor heat distribution, or an upset that overheats part of a tube or pressure boundary. The increased metal temperature rapidly reduces the material’s high-temperature strength, allowing deformation to accumulate under the existing pressure load in a relatively short period—potentially hours or days rather than a prolonged service interval.

The visible morphology follows directly from this mechanism. Localized creep deformation produces a swollen or bulged area and corresponding wall thinning. If rupture occurs, the opening may have a characteristic fish-mouth appearance. These physical indicators are important in failure investigation because they identify the overheated area and support evaluation of operating temperature, heat-transfer conditions, and load history. API’s corrosion and materials guidance is published as API RP 571; consult the current publication and associated API standards resources at API Standards and API Standards Announcements.

QUESTION NO: 34

Low alloy steels contain a maximum of _______ chrome.

A. 5%

B. 6%

C. 7.5%

D. 9%

ANSWER: D

Explanation:

9% is correct. In the refinery and petrochemical context used by API RP 571, low-alloy steels include chromium-molybdenum steels with chromium contents ranging up to approximately 9% chromium. These materials are commonly described by nominal compositions such as 1¼Cr-½Mo, 2¼Cr-1Mo, 5Cr-½Mo, and 9Cr-1Mo. Chromium is deliberately added to improve elevated-temperature strength and resistance to oxidation and sulfidation, while molybdenum contributes to high-temperature creep strength and hydrogen-related damage resistance. The 9Cr family remains classified as low-alloy steel in this practical API materials grouping; steels with substantially higher chromium contents are generally considered within stainless-steel or other high-alloy material families. Therefore, for the requested maximum chromium content of low-alloy steels, 9% is the applicable limit. API RP 571 provides damage-mechanism guidance for fixed equipment and discusses the material behavior relevant to these chromium-molybdenum alloy steels. See the API Standard 571 information page and API’s standards catalog for the governing industry-reference framework.

QUESTION NO: 35

__________ are the most common type of equipment susceptible to carburization in the refining industry.

A. Reactors

B. Heat exchangers

C. Heater tubes

D. Fin Fans

ANSWER: C

Explanation:

Heater tubes are the most common type of equipment susceptible to carburization in refinery service because they operate for long periods at the elevated metal temperatures needed for this damage mechanism. Carburization is the absorption and diffusion of carbon into an alloy exposed to carbonaceous gases or process fluids at high temperature. The resulting increase in carbon content and carbide formation can alter the tube's microstructure, reduce ductility and creep-rupture strength, and make damage particularly significant where tube reliability and remaining life are critical. Fired-heater tubes combine the principal conditions associated with carburization: sustained high skin temperatures, exposure to hydrocarbon-containing process streams on the inside, and long operating campaigns. The applicable materials and exact susceptibility depend on alloy composition, temperature, carbon activity, and the service environment, but heater-tube circuits are the characteristic refinery application emphasized when screening for this form of high-temperature degradation. Inspection and life-assessment planning should therefore account for carburization where the heater's process conditions and tube-metal temperatures fall within the applicable damage regime. API 571 is the industry reference for identifying damage mechanisms and their affected equipment: API RP 571. Additional technical background on high-temperature corrosion mechanisms and materials behavior is available from AMPP.

QUESTION NO: 36

Many thermal fatigue cracks are filled with:

A. chlorides.

B. hydroslime.

C. oxides.

D. sulfides.

ANSWER: C

Explanation:

oxides. Thermal fatigue results from cyclic temperature changes that produce repeated expansion and contraction, causing cracking where thermal stresses are concentrated. At the elevated temperatures where this damage commonly occurs, crack surfaces are exposed to an oxidizing environment. Oxidation products form on the newly exposed metal surfaces during thermal cycling and can progressively accumulate within the crack. Consequently, many thermal-fatigue cracks have an oxide-filled appearance. This characteristic can assist inspection personnel in identifying thermal fatigue and distinguishing its service history from cracking mechanisms associated with other environmental conditions. API RP 571 describes thermal fatigue as a form of mechanical fatigue induced by cyclic thermal stresses and notes that cracks are often filled with oxides. The relevant damage-mechanism guidance is available from the API RP 571 publication page. Additional technical context on high-temperature oxidation and its relationship to material degradation is provided by the U.S. Department of Energy technical resource on high-temperature oxidation.

QUESTION NO: 37

Damage from oxidation is usually determined by:

A. Metallographic examination

B. Ultrasonic thickness measurements

C. Hardness testing

D. Hammer testing

ANSWER: B

Explanation:

Ultrasonic thickness measurements is correct because high-temperature oxidation consumes metal at the exposed surface as oxide scale forms, resulting in progressive wall loss. The practical inspection objective is therefore to establish the remaining component thickness and compare it with the required minimum thickness or an established corrosion-rate trend. Ultrasonic testing provides a nondestructive, quantitative means of measuring this remaining wall thickness over broad areas, including locations where oxidation may be nonuniform. Repeated readings at defined condition-monitoring locations can identify continuing metal loss, support remaining-life calculations, and guide repair or replacement decisions. API 571 describes oxidation as a high-temperature damage mechanism involving scale formation and metal wastage, so thickness monitoring is the usual way to assess its severity in service. API RP 574 likewise identifies ultrasonic thickness measurement as a principal method for determining wall loss during piping inspection. See the API 571 standard listing at API 571 and API's inspection guidance listing for API RP 574.

QUESTION NO: 38

__________ is a form of cracking that results when certain molten metals come in contact with specific alloys. Cracking can be very sudden and brittle in nature.

A. SCC

B. LME

C. AET

D. SOHIC

ANSWER: B

Explanation:

LME is the correct answer. Liquid metal embrittlement is a cracking mechanism that can occur when a susceptible solid alloy is exposed to a particular liquid metal under tensile stress. The liquid metal wets the alloy surface and penetrates susceptible microstructural paths, substantially reducing ductility and allowing cracks to initiate and propagate with little plastic deformation. Consequently, damage can appear abruptly and have a brittle character, as described in the question. In refining and petrochemical equipment, API 571 identifies liquid metal embrittlement as a relevant damage mechanism where molten metals such as zinc, lead, tin, cadmium, or mercury contact susceptible materials in the appropriate temperature range. The precise risk depends on the liquid-metal/solid-alloy combination, temperature, exposure conditions, and stress state. API 571 is the principal industry reference for recognizing this mechanism during materials selection, inspection planning, damage assessment, and failure investigation. The mechanism is also described in the ASM Materials Damage reference as environmentally assisted cracking caused by contact between a liquid metal and a stressed susceptible solid metal. See API Recommended Practice 571 and ASM Handbook: Materials Damage Mechanisms.

QUESTION NO: 39

Which of the following is related to all wet H_2S damage mechanisms?

A. pH of <7 with dissolved H_2S present

B. Localized zones of weld HAZ hardness above 200 HB

C. Water vapor in the hydrocarbon phase

D. Absorption and permeation of hydrogen

ANSWER: D

Explanation:

Absorption and permeation of hydrogen is related to every wet H_2S damage mechanism because aqueous corrosion in an H_2S-containing environment produces atomic hydrogen at the steel surface. H_2S interferes with the normal recombination of atomic hydrogen into molecular hydrogen, increasing the amount of hydrogen that enters the metal. Once absorbed, hydrogen can diffuse through the steel and concentrate at microstructural trap sites such as inclusions, laminations, dislocations, interfaces, and highly stressed regions. This hydrogen uptake is the common initiating feature underlying the forms of wet H_2S damage addressed in API RP 571, including hydrogen blistering, hydrogen-induced cracking, stress-oriented hydrogen-induced cracking, and sulfide stress cracking. The subsequent damage morphology depends on material properties, stress, hardness, fabrication details, microstructure, and the specific wet-service conditions, but each mechanism requires hydrogen generation at the corroding surface and its entry into the steel. Therefore, identifying hydrogen absorption and permeation captures the shared electrochemical and metallurgical basis of wet H_2S cracking and blistering damage. API's corrosion-mechanism guidance is available through the API RP 571 standard information page; associated sour-service material requirements are addressed by AMPP MR0175/ISO 15156.

QUESTION NO: 40

(In an RBI assessment, sulfidation was identified as a credible damage mechanism and assigned a corrosion rate of 8 mpy (0.20 mm/yr). Which of the following are critical factors in sulfidation?)

A. Concentration of sulfur species and operating temperature

B. Operating temperature and corrosion rate

C. Concentration of sulfur species, operating temperature, and metallurgy

D. Corrosion rate and concentration of sulfur species

ANSWER: C

Explanation:

"Concentration of sulfur species, operating temperature, and metallurgy" is correct because these are the principal variables governing sulfidation corrosion in refinery and petrochemical equipment. Sulfidation is high-temperature corrosion caused by sulfur-containing compounds in process streams. Its severity depends on the sulfur activity or concentration in the environment, which determines the driving force for sulfide-scale formation; the operating metal temperature, which strongly affects reaction kinetics and scale behavior; and the alloy composition of the component. Metallurgy is particularly important because chromium-bearing steels and alloys generally provide substantially better resistance than carbon steel by developing more protective scales under suitable service conditions. These factors must be evaluated together when identifying susceptible circuits and estimating an RBI damage rate. The stated corrosion rate is an assessment output used to project metal loss and remaining life; it does not itself define the underlying process and material conditions that control sulfidation susceptibility. API RP 571 categorizes sulfidation as a damage mechanism and describes the importance of temperature, sulfur compounds, and alloy composition when evaluating affected equipment. See the API 571 standard information page and API's standards catalog.

QUESTION NO: 41

________ and _______ damage develop without applied or residual stress so that PWHT will not prevent them from occurring.

A. SOHIC, Blistering

B. SCC, SOHIC

C. HIC, SCC

D. Blistering, HIC

ANSWER: D

Explanation:

Blistering, HIC is correct because both mechanisms can initiate and propagate as a consequence of atomic hydrogen entering susceptible steel and accumulating at internal trapping sites, without a requirement for applied loading or residual welding stress. In wet hydrogen sulfide environments, hydrogen generated by corrosion reactions can diffuse into the steel. Hydrogen may recombine to molecular hydrogen at inclusions, laminations, and other discontinuities, creating internal pressure that produces hydrogen blisters. Hydrogen-induced cracking occurs when the local hydrogen concentration and material susceptibility promote planar cracking through the steel, commonly associated with inclusions and segregated microstructures.

Postweld heat treatment is principally used to reduce residual stresses and can be valuable where stress-dependent cracking is a concern. Since blistering and hydrogen-induced cracking do not depend on those stresses to develop, stress relief by itself does not prevent them. Effective control instead relies on selecting appropriately resistant plate or weld materials, controlling hardness and steel cleanliness where applicable, evaluating the sour-service environment, and using fabrication and inspection practices suited to hydrogen damage risk. API 571 identifies and describes these corrosion and materials damage mechanisms for fixed equipment; see the API 571 standard information and the API standards catalog.

QUESTION NO: 42

Sulfuric acid promotes general and localized corrosion of carbon steel. Carbon steel heat affected zones may experience severe corrosion. Acid concentration, temperature, alloy content and ____________ are critical factors affecting sulfuric acid corrosion.

A. Pressure

B. Stress

C. Velocity

D. Ductility

ANSWER: C

Explanation:

Velocity is correct because sulfuric-acid corrosion of carbon steel is strongly influenced by fluid flow and mass transfer at the metal surface. In many sulfuric-acid services, corrosion behavior depends on whether a protective corrosion-product layer can form and remain attached. Increased liquid velocity, turbulence, impingement, or other high-flow conditions can strip or prevent formation of that layer, continually expose fresh steel, and accelerate metal loss. Flow also replenishes acid at the surface and transports dissolved corrosion products away, which can increase the corrosion rate compared with low-velocity or stagnant conditions.

The effect is not isolated from the other stated variables. Sulfuric-acid concentration and temperature determine the corrosiveness of the environment, while alloy chemistry affects the material's resistance. Velocity is the additional operating variable that can substantially alter the practical corrosion rate and distribution, particularly at elbows, restrictions, pump discharge areas, injection points, and locations subject to impingement. This aligns with API 571's treatment of sulfuric-acid corrosion as a damage mechanism whose severity is affected by process conditions, including velocity. See the API 571 standard information and the Inspectioneering sulfuric acid corrosion resources.

QUESTION NO: 43

A condition where steel loses strength due to the removal of carbon and carbides leaving only an iron matrix is called decarburization. This occurs during high temperatures, during PWHT and from exposure to fires. Which of the following materials is not affected by this?

A. Low alloy steel

B. Duplex SS

C. Carbon steel

D. None of the above

ANSWER: B

Explanation:

Duplex SS is correct because decarburization is principally a degradation mechanism for carbon steels and low-alloy steels. At elevated temperature in an oxidizing or otherwise carbon-removing environment, carbon can diffuse from the steel surface and react to form gaseous products. The resulting carbon-depleted layer has reduced carbide content and can exhibit lower strength and hardness than the unaffected base metal. Duplex stainless steel is not considered susceptible to decarburization in the API 571 sense because its corrosion resistance and mechanical properties are derived primarily from its chromium-rich duplex ferritic-austenitic structure rather than from the carbon and iron-carbide strengthening system characteristic of carbon and low-alloy steels. Duplex grades are deliberately low in carbon, and their metallurgy is controlled chiefly through chromium, nickel, molybdenum, nitrogen, and phase balance. API 571 identifies decarburization as a high-temperature damage mechanism relevant to carbon and low-alloy steels, including exposure during heat treatment or fire events. Inspection and material-evaluation decisions should therefore focus on whether the component is a carbon or low-alloy steel and whether it experienced an appropriate high-temperature carbon-removing exposure. See API RP 571 information and Nickel Institute technical guides.

QUESTION NO: 44

Nitriding is usually confined to the surface of most components and will have a dull, ______ appearance. In more advanced stages, the material will exhibit very hard surface hardness.

A. Gray

B. Black

C. Brown

D. White

ANSWER: A

Explanation:

Gray is correct. Nitriding is a surface-related high-temperature corrosion mechanism in which nitrogen is absorbed into susceptible alloys, particularly certain low-alloy and carbon steels, at elevated temperatures. Because the reaction is generally concentrated near the exposed metal surface, visual examination can show a dull gray surface appearance rather than a bright metallic finish. As nitriding progresses, nitrogen-rich phases and related microstructural changes develop near the surface. These changes produce the characteristic marked increase in surface hardness referenced in the question. The combination of a dull gray appearance and unusually hard surface material is therefore a useful field indicator that should prompt further inspection and metallurgical assessment where operating temperature, alloy chemistry, and nitrogen-containing process conditions make nitriding credible. API 571 is the petroleum-industry reference for identifying this and other fixed-equipment damage mechanisms, including their appearance, affected materials, and inspection considerations. The described visual and hardness characteristics align with the mechanism’s surface-localized nature and progressive embrittling effect. See the API 571 standard information and the API standards catalog for the governing damage-mechanism reference context.

QUESTION NO: 45

Thermal fatigue becomes of concern if the temperature swings exceed:

A. 50 oF.

B. 100 oF.

C. 200 oF.

D. 400 oF.

ANSWER: C

Explanation:

200 oF. is correct. Thermal fatigue results from cyclic thermal expansion and contraction that produces repeated stress and strain, particularly where a component has geometric discontinuities, restraints, temperature gradients, or connections between materials or sections that respond differently to heating and cooling. API 571 identifies thermal fatigue as a concern when temperature swings exceed approximately 200°F (100°C). At this magnitude, cyclic differential expansion can create stresses sufficient to initiate and propagate fatigue cracks, commonly at locations such as mixing points, deadlegs, nozzles, supports, and thick-to-thin transitions. The damage mechanism is driven not simply by the operating temperature, but by the range, frequency, rate, and nonuniformity of the temperature cycles, along with the component's restraint and geometry. Thus, identifying repeated swings at or above 200°F is an important screening criterion for inspection planning and for evaluating susceptible piping and equipment. API 571 provides industry guidance on this and other damage mechanisms used in refinery and petrochemical fixed-equipment integrity programs. See the API 571 standard information page and API's standards catalog.

QUESTION NO: 46

____________ are characterized by a localized loss in thickness in the form of pits, grooves, gullies, waves, rounded holes and valleys. These losses often exhibit a directional pattern.

A. Erosion

B. Erosion/Erosion-Corrosion

C. Environmental corrosion

D. Both erosion and erosion-corrosion

ANSWER: D

Explanation:

Both erosion and erosion-corrosion are characterized by the stated morphology. API 571 treats erosion/erosion-corrosion as a damage mechanism involving localized metal loss caused by relative movement or impingement of solids, liquids, vapor, or multiphase streams. The characteristic surface profile can include pits, grooves, gullies, waves, rounded holes, and valleys. Because the damage is driven by the flow path, particle impingement angle, turbulence, or changes in velocity, the resulting thinning commonly has a directional pattern that follows the process stream or impact trajectory.

Erosion is mechanical removal of material, while erosion-corrosion includes the combined action of mechanical wear and corrosion in a moving corrosive environment. The question's wording intentionally encompasses both forms because either can produce the specified localized and directionally oriented appearance. This terminology and morphology are addressed under the erosion/erosion-corrosion damage-mechanism coverage in API Recommended Practice 571. API 571 is used with the inspection and damage-assessment practices described in the API standards program: API Standards.

QUESTION NO: 47

Refractory anchors must be resistant to __________ in high temperature services.

A. Thermal fatigue

B. Thermal cracking

C. Stress cracking

D. Oxidation

ANSWER: D

Explanation:

Oxidation is correct because refractory anchors operate within, or immediately behind, refractory linings that are exposed to sustained elevated temperatures. At these temperatures, metallic anchor materials can react with available oxygen and form oxide scale. Progressive oxidation consumes the anchor cross-section, reduces mechanical strength, and can ultimately cause anchor failure, allowing refractory to crack, loosen, or detach. Anchor alloy selection therefore must consider the expected metal temperature and provide adequate oxidation resistance for the specific high-temperature environment. This is especially important because the refractory may insulate portions of the equipment unevenly, while anchors can remain subject to severe thermal exposure for long periods. API RP 571 identifies refractory degradation and the importance of suitable anchor material in high-temperature service damage considerations. The governing material selection and inspection approach should also account for the actual process atmosphere, temperature excursions, and expected service life. See the API listing for API RP 571, Damage Mechanisms Affecting Fixed Equipment in the Refining Industry and the API Standards catalog.

QUESTION NO: 48

Which of the following does not increases the likelihood of atmospheric corrosion?

A. Bird poop

B. Increasing annual rainfalls

C. Locations where moisture is trapped

D. Increasing operating pressures

E. Increasing amounts of airborne contaminates

ANSWER: D

Explanation:

Increasing operating pressures is correct because atmospheric corrosion is an external damage mechanism driven primarily by exposure of a metal surface to an electrolyte film and corrosive constituents in the surrounding environment. Its likelihood is governed by time of wetness, relative humidity, rainfall, temperature cycling, surface deposits, and airborne contaminants such as salts or industrial pollutants. Local geometry that retains water or deposits can further prolong wetness and create highly corrosive conditions. These are the types of conditions addressed in API 571's discussion of atmospheric corrosion, including the importance of wet/dry cycling and contaminant deposition on external surfaces.

Operating pressure is an internal process condition. Although pressure may be relevant to equipment design, mechanical integrity, and certain internal corrosion or cracking mechanisms, raising it does not itself increase the external availability of moisture, oxygen, or deposited contaminants required for atmospheric corrosion. Therefore, without a corresponding change in the external environment or surface temperature that produces condensation, an increase in operating pressure does not make atmospheric corrosion more likely. See the API reference for API RP 571 and the International Molybdenum Association overview of atmospheric corrosion.

QUESTION NO: 49

Corrosion in boiler feedwater and condensate return systems is usually the result of dissolved gases, oxygen and ________.

A. Carbon monoxide

B. Carbon dioxide

C. Material properties

D. H²S

ANSWER: B

Explanation:

Carbon dioxide is correct because it is a principal dissolved gas responsible for corrosion in boiler feedwater and, especially, condensate-return systems. Carbon dioxide can enter with makeup water or be generated when boiler heat decomposes bicarbonate and carbonate alkalinity. It travels with the steam and dissolves as the steam condenses in return piping. The resulting carbonic acid reduces condensate pH and promotes general thinning and characteristic grooving or pitting of carbon-steel condensate lines. Dissolved oxygen is also significant because it depolarizes the cathodic reaction and can produce localized oxygen-attack pitting; together, oxygen and carbon dioxide are the standard dissolved-gas corrosion concerns addressed by deaeration, chemical oxygen scavenging where applicable, condensate pH control, and neutralizing or filming amines. API RP 571 describes carbon-dioxide corrosion as arising when CO_2 dissolves in water to form carbonic acid and identifies boiler and condensate systems as relevant aqueous-service environments. The U.S. Department of Energy likewise explains that carbon dioxide in condensate forms carbonic acid, making condensate acidic and corrosive. These mechanisms make carbon dioxide the intended completion of the question. See API RP 571 and U.S. Department of Energy Steam System Survey Guide.

QUESTION NO: 50

Which of the following is a critical factor for chloride stress corrosion cracking?

A. Presence of nickel content less than 8%

B. Presence of oxygen

C. Presence of nickel content higher than 35%

D. Use in an alkaline pH region

ANSWER: B

Explanation:

Presence of oxygen is a critical factor for chloride stress corrosion cracking (Cl-SCC), particularly in aqueous or wet-service environments involving susceptible austenitic stainless steels and certain nickel alloys. API RP 571 identifies the combined role of chlorides, tensile stress, susceptible material, and temperature in this damage mechanism. Oxygen is especially important because it supports cathodic reactions and promotes localized corrosion, including pitting and crevice corrosion. These localized sites can concentrate chlorides and create aggressive occluded conditions that facilitate initiation of stress-corrosion cracks under tensile stress.

Chloride concentrations do not need to be high for this mechanism to become credible; contamination at relatively low levels can be consequential when moisture, oxygen, elevated metal temperature, and residual or applied tensile stresses are also present. In practice, oxygen ingress through atmospheric exposure, insulation wetting, poor drainage, leaks, or contamination can therefore increase the likelihood of crack initiation. Evaluating Cl-SCC susceptibility requires considering the complete operating and environmental condition rather than chloride content alone. API RP 571 describes this mechanism and its applicable materials, environments, and damage characteristics in its damage-mechanism guidance. See the API standards catalog and the Nickel Institute technical guides for additional corrosion-engineering resources.

QUESTION NO: 51

Sigma phase in welds can be minimized by controlling ferrite in the range of _________ for Type 347 SS.

A. 3%-5%

B. 5%-7%

C. 7%-9%

D. 5%-9%

ANSWER: D

Explanation:

5%-9% is the appropriate ferrite range for Type 347 stainless-steel weld metal when the objective is to minimize sigma-phase formation. In this alloy system, weld metal commonly contains some delta ferrite to improve resistance to hot cracking during solidification. However, delta ferrite can transform during prolonged exposure at elevated temperatures into brittle intermetallic constituents, including sigma phase. Maintaining ferrite at a controlled, moderate level provides the needed weldability benefit while limiting the amount of ferritic phase available for this transformation. API 571 identifies sigma phase as an elevated-temperature damage mechanism in austenitic stainless steels and recognizes the importance of weld-metal ferrite control for susceptible materials such as Type 347 stainless steel. The stated 5%-9% range is therefore a practical composition-control target used when selecting filler metal and establishing welding procedures for this service. Ferrite control should be verified through qualified welding procedures and, where required, ferrite measurement methods appropriate to the deposited weld metal. See API Recommended Practice 571 and TWI's technical overview of sigma phase.

QUESTION NO: 52

Units where graphitization may be suspected are the FCCU and the _____ unit.

A. Hydrotreater

B. Coker

C. Alky

D. None of the above

ANSWER: B

Explanation:

Coker is correct because graphitization is a high-temperature deterioration mechanism that can affect carbon steel and carbon-molybdenum steels after long exposure in the graphitization temperature range. It involves conversion or redistribution of carbides into graphite, which may reduce strength, ductility, toughness, and creep resistance. In refinery service, coker equipment can contain components that have operated for extended periods at temperatures where this damage mechanism is credible, particularly older carbon-steel or C-0.5Mo pressure-boundary materials. FCCU equipment is likewise a recognized refinery location for considering graphitization because of its elevated-temperature operating history. Inspection planning should therefore consider the actual material, metal-temperature history, time at temperature, and locations where loss of mechanical properties could create an integrity concern. Metallographic replication and targeted sampling, when justified by the damage review, can help establish whether graphitic microstructural changes are present. API 571 identifies graphitization among the damage mechanisms relevant to fixed equipment and provides the basis for screening susceptible materials and operating conditions. See the API 571 standard information and TWI's technical overview of graphitization.

QUESTION NO: 53

Annealed steels are more resistant to Spheroidization than normalized steels. _________ grained steels are more resistant than ______ grained steels.

A. Fine, Coarse

B. Coarse, Fine

C. PWHT, Non-PWHT

D. Non-PWHT, PWHT

ANSWER: A

Explanation:

Fine, Coarse is correct. Spheroidization is a high-temperature, time-dependent microstructural change in carbon and low-alloy steels in which lamellar or plate-like carbides progressively become rounded and dispersed. This change reduces strength and hardness and can be significant in components that operate for extended periods in the applicable elevated-temperature range. Fine-grained steel is more resistant because its finer grain structure provides a more stable microstructure and a greater grain-boundary area that helps retard carbide coarsening and the associated loss of strength. Coarse-grained material has less resistance to this degradation mechanism. The statement is consistent with API 571 guidance on spheroidization, which identifies grain size as a metallurgical factor affecting susceptibility and notes the comparatively greater resistance of fine-grained steels. In practice, confirming the material's heat treatment, grain-size condition, operating temperature, and accumulated exposure time is important when evaluating possible spheroidization damage. API 571 is the industry reference for identifying this and other damage mechanisms in refinery and petrochemical equipment; see the API 571 standard information page and the API standards catalog.

QUESTION NO: 54

In order for PASCC to occur the material must be ______.

A. PWHT

B. Non-PWHT

C. Sensitized

D. Austenetic

ANSWER: C

Explanation:

Sensitized is correct because polythionic acid stress corrosion cracking (PASCC) is an intergranular cracking mechanism associated principally with sensitized austenitic stainless steels in wet sulfur-containing refinery environments. Sensitization occurs when an austenitic stainless steel spends time in a temperature range that permits chromium carbides to precipitate at grain boundaries. This locally reduces the chromium available to maintain corrosion resistance beside those boundaries. If a sensitized component is subsequently exposed to water and sulfur species that form polythionic acids, commonly during shutdown, air ingress, steaming, washing, or hydrotesting, preferential grain-boundary attack can develop. Applied or residual tensile stress can then propagate the intergranular cracking characteristic of PASCC. Thus, the material condition required by the question is sensitization; it establishes the susceptible grain-boundary microstructure necessary for this damage mechanism. API 571 identifies polythionic acid cracking as a damage mechanism affecting sensitized austenitic stainless steels and emphasizes the importance of material condition and exposure environment. See the API 571 standard information and the TWI explanation of sensitisation in stainless steels.

QUESTION NO: 55

Increasing the chromium in steels offers no major improvement in resistance to CO² corrosion until a minimum of __________ is reached.

A. 9%

B. 12%

C. 5%

D. 7%

ANSWER: B

Explanation:

12% is correct. API 571 identifies a minimum chromium content of approximately 12% as the point at which steels gain a major improvement in resistance to carbon-dioxide corrosion. Below this level, chromium additions do not generally provide the substantial benefit associated with chromium-rich corrosion-resistant alloys in wet CO_2 service. At about 12% chromium, the alloy can form and maintain a more protective chromium-containing surface film under suitable process conditions, reducing the rate of general metal loss caused by carbonic acid produced when CO_2 dissolves in water.

This threshold is particularly relevant when evaluating material selection for production, gathering, and process equipment that may contain free water and CO_2. Actual performance still depends on operating temperature, CO_2 partial pressure, pH, flow regime, water chemistry, chloride content, oxygen ingress, and the tendency for localized corrosion or film breakdown. Consequently, 12% chromium is the recognized minimum for a major improvement, not a guarantee of acceptable performance in every CO_2-containing environment. The statement is consistent with the CO_2-corrosion guidance in API 571; users should apply the current edition together with service-specific corrosion assessment and materials-selection practices. See API Standard 571 and AMPP corrosion resources for the oil and gas industry.

QUESTION NO: 56

(For hydrogen embrittlement, the amount of hydrogen necessary for a measurable effect on the mechanical properties varies with the alloy's strength, microstructure, and:)

A. Modulus of elasticity

B. Coefficient of thermal conductivity

C. Melting point

D. Heat treatment

ANSWER: D

Explanation:

Heat treatment is correct because hydrogen embrittlement susceptibility is governed not only by the quantity of diffusible hydrogen present, but also by the material condition produced through thermal processing. Heat treatment can change strength level, hardness, residual stresses, precipitate distribution, grain-boundary characteristics, and the density and nature of microstructural hydrogen-trapping sites. These changes affect both hydrogen transport and the tendency for localized hydrogen-assisted cracking or loss of ductility under stress. Consequently, an identical hydrogen concentration can have very different mechanical consequences in the same nominal alloy after different quenching, tempering, stress-relieving, annealing, welding, or post-weld heat-treatment histories. This relationship is particularly important for high-strength steels, where harder or higher-strength heat-treated conditions generally have a lower tolerance for diffusible hydrogen and can crack after a delay while under tensile stress. The API damage-mechanism guidance treats hydrogen embrittlement as a condition dependent on material strength and metallurgical condition, including thermal history. Heat treatment is therefore the material-related variable that completes the stated relationship. See the API corrosion and materials guidance overview for API RP 571 and the technical discussion of hydrogen effects in steel from TWI.

QUESTION NO: 57

Major factors affecting sulfidation are alloy composition, temperature and ________.

A. Time

B. Stress

C. Concentration of hydrogen

D. Concentration of sulfur

ANSWER: D

Explanation:

Concentration of sulfur is correct because high-temperature sulfidation is driven by sulfur-containing species in the process stream. API 571 identifies alloy composition, metal temperature, and sulfur content as the principal factors governing this damage mechanism. As temperature rises, sulfur species can react with exposed metal surfaces to form iron sulfide scale and cause metal loss. The sulfur level in the fluid therefore directly affects the environment's sulfidizing severity; in practical refinery service, the form, activity, and partial pressure of sulfur-bearing compounds also influence the corrosion rate. Alloy composition matters because chromium-bearing alloys generally provide better resistance by forming more protective scales under suitable conditions, while temperature controls reaction kinetics and scale stability. Accordingly, identifying the sulfur concentration in the operating stream is essential when evaluating expected sulfidation rates, selecting materials, and establishing inspection plans for hot hydrocarbon and sulfur-containing process equipment. API's description of API RP 571 identifies it as the refinery damage-mechanism reference used to understand these process-related corrosion threats. See API Recommended Practice 571 and API Standards.

QUESTION NO: 58

The sudden rapid fracture under stress (residual or applied) where the material exhibits little or no evidence of ductility or plastic deformation is called _________.

A. 885º F Embrittlement

B. Temper Embrittlement

C. Stress Corrosion Cracking

D. Brittle Fracture

ANSWER: D

Explanation:

Brittle Fracture is the correct term for a sudden, rapid structural failure occurring under residual or applied stress with little or no plastic deformation. In this damage mechanism, a crack can propagate very quickly once the material's resistance to fracture is exceeded, rather than being preceded by appreciable yielding, necking, or other visible ductile deformation. API RP 571 describes brittle fracture as a catastrophic cracking mechanism that may occur with minimal warning when susceptible materials are exposed to conditions such as low temperature, high stress, material embrittlement, or stress-concentrating flaws. The fracture appearance is commonly associated with a flat, crystalline-looking surface and may follow a cleavage-type path through the metal. The key identifying feature in the question is the combination of sudden rapid fracture and the absence, or near absence, of ductility or plastic deformation; this is the defining behavior of brittle fracture. A sound understanding of brittle-fracture susceptibility is important for pressure equipment because its onset can be abrupt and can lead to loss of containment. See the API publication page for API RP 571 and the U.S. Nuclear Regulatory Commission's technical discussion of brittle fracture.

QUESTION NO: 59

Thermal fatigue cracks usually initiate on the _________ of the component. They are generally wide and filled with oxides due to the elevated temperatures.

A. Surface

B. ID

C. Welds

D. None of the above

ANSWER: A

Explanation:

Surface is correct because thermal fatigue damage results from repeated temperature changes that produce cyclic thermal expansion and contraction. At a component surface, rapid heating or cooling commonly creates the greatest temperature gradient between the exposed material and the cooler or hotter underlying section. This gradient produces cyclic tensile and compressive stresses, and cracks tend to initiate at the surface where stress concentration, oxidation, and local restraint effects are present. Once initiated, thermal-fatigue cracks propagate inward from the exposed surface during subsequent thermal cycles. In elevated-temperature service, the crack faces are exposed to an oxidizing environment; oxide scale forms repeatedly as the crack opens and closes. This is why the cracking is characteristically relatively wide and oxide-filled, a useful visual feature during external examination or metallographic evaluation. API 571 identifies thermal fatigue as a damage mechanism associated with cyclic thermal stresses and describes the characteristic surface-origin cracking morphology. See the API 571 publication listing at API Webstore—API Recommended Practice 571 and API's standards information at API Standards.

QUESTION NO: 60

Most brittle failures appear as:

A. Branched cracking.

B. Intergranular cracking.

C. Ductile tears.

D. Cleveage.

ANSWER: D

Explanation:

Cleveage is correct; the intended metallurgical term is “cleavage.” Brittle fracture generally propagates with very little plastic deformation and therefore does not produce the stretched, fibrous appearance associated with ductile overload. Instead, fracture commonly travels along specific crystallographic planes within grains, producing a flat or faceted surface morphology known as cleavage. These facets may form characteristic patterns such as river markings, which indicate the local direction in which the crack advanced as separate cleavage planes merged. At the component scale, brittle fracture can occur suddenly and can propagate rapidly once a critical crack size, stress level, and unfavorable combination of temperature, material toughness, and constraint are present. API 571 addresses brittle fracture as a damage mechanism of concern for pressurized equipment, particularly when low temperature, high stress, flaws, or susceptible materials reduce resistance to crack propagation. Correct recognition of cleavage morphology during failure analysis supports distinguishing a brittle mechanism from a ductile overload mechanism and helps guide evaluation of toughness, operating temperature, and material condition. See the API 571 standard information and the Britannica discussion of cleavage fracture.

QUESTION NO: 61

Stainless steels with sigma can normally withstand normal operating stresses but upon cooling to temperatures below ________ may show a complete lack of fracture toughness as measured by a Charpy impact test.

A. 800º F

B. 600º F

C. 500º F

D. 400º F

ANSWER: C

Explanation:

500º F is correct. Sigma phase is a hard, brittle, chromium-rich intermetallic phase that can form in susceptible austenitic and duplex stainless steels after exposure within an elevated-temperature range. Although material containing sigma phase may continue to support ordinary operating loads at elevated temperature, its ductility and fracture toughness can be severely impaired. API 571 identifies the important practical consequence: when such material is cooled below approximately 500º F, it may exhibit essentially no fracture toughness in a Charpy impact test. This behavior creates a significant brittle-fracture concern during shutdown, start-up, hydrotesting, depressuring, or other conditions in which a sigma-embrittled component is at lower metal temperature while stressed.

The Charpy impact test is particularly relevant because it measures absorbed impact energy and is used to characterize a material’s resistance to brittle fracture under dynamic loading conditions. The 500º F value is therefore not the temperature at which sigma forms; it is the approximate temperature below which the embrittlement’s loss of impact toughness becomes especially consequential. API 571 covers sigma-phase embrittlement as a high-temperature damage mechanism and emphasizes evaluating both the prior thermal exposure and the component’s anticipated low-temperature service conditions. See the API 571 standard information and ASM International materials resources.

QUESTION NO: 62

Protection in a boiler from boiler feed water corrosion is accomplished by:

A. Injecting chlorines to kill microbiological bugs.

B. Injecting caustic to lower the ph to < 4.0.

C. Lowering solids content in boiler feed water to less than 50 ppm.

D. Maintaining a protective corrosion layer of magnetite (Fe_3O_4).

ANSWER: D

Explanation:

Maintaining a protective corrosion layer of magnetite (Fe_3O_4) is correct. In properly controlled boiler and feedwater systems, iron-based surfaces develop a dense, adherent magnetite film that acts as a protective barrier between the metal and the water/steam environment. Effective feedwater treatment supports formation and retention of this passive oxide layer by controlling dissolved oxygen, pH, and reducing conditions. Oxygen scavenging and appropriate chemical treatment are particularly important because oxygen ingress can disrupt the protective film and promote localized oxygen-related corrosion. API RP 571 identifies boiler-water corrosion as a damage mechanism influenced by water chemistry and notes that corrosion control depends on maintaining appropriate boiler-water treatment conditions. Magnetite is also a principal corrosion-product oxide in high-temperature aqueous steam-cycle environments and, when stable and adherent, reduces further metal loss. Treatment programs must be tailored to boiler pressure, metallurgy, condensate quality, and system design, with routine monitoring used to confirm that chemistry remains within the applicable operating limits. See API RP 571 information and the EPRI guidance on fossil and combined-cycle chemistry.

QUESTION NO: 63

______ is similar to HIC but is a potentially more damaging form of cracking which appears as arrays of cracks stacked on top of each other. The result is a through thickness crack that is perpendicular to the surface and is driven by high levels of stress.

A. MIC

B. SOHIC

C. Sulfuric SCC

D. None of the above

ANSWER: B

Explanation:

SOHIC is the correct term because it describes stress-oriented hydrogen-induced cracking: a cracking morphology associated with wet hydrogen sulfide service in susceptible steels. It is related to hydrogen-induced cracking because hydrogen enters the steel and accumulates at metallurgical trap sites, but SOHIC becomes more severe when applied or residual tensile stress directs and links the individual hydrogen-related cracks. The characteristic appearance is a series of small cracks aligned in a stacked, stepwise array through the wall. As these cracks coalesce, they can form a through-thickness crack oriented approximately perpendicular to the stressed surface, creating a significant threat to pressure-boundary integrity. API 571 identifies SOHIC as a hydrogen-damage mechanism and distinguishes its stress-assisted, stacked-crack morphology from conventional hydrogen-induced cracking. Appropriate damage assessment therefore considers wet hydrogen sulfide exposure, material susceptibility, welding and fabrication details, and locations of elevated tensile stress. See the API 571 standard information page and the ASTM G39 guidance on stress-corrosion cracking testing for related technical context on stress-assisted cracking evaluation.