EXAMPLES OF RECOGNIZED AND GENERALLY ACCEPTED GOOD ENGINEERING PRACTICES

Reference: *Guidelines for Mechanical Integrity Systems, Center for Chemical Process Safety of the American Institute of Chemical Engineers*

CONTENTS:

ACRONYMS AND ABBREVIATIONS

ACC	American Chemistry Council
ACCP	ASNT Central Certification Program
ACGIH	American Conference of Governmental Industrial Hygienists
AIChE	American Institute of Chemical Engineers
ALARP	as low as reasonably practicable
ANSI	American National Standards Institute
API	American Petroleum Institute
ASM	American Society for Metals (ASM International)
ASME	American Society of Mechanical Engineers
ASNT	American Society of Non-destructive Testing
ASTM	American Society of Testing and Materials (ASTM International)
AWS	American Welding Society
BPVC	Boiler and Pressure Vessel Code
CCPS	Center for Chemical Process Safety
CF	causal factor
CFR	*Code of Federal Regulations*
CI	Chlorine Institute
CM	condition monitoring
CMMS	computerized maintenance management system
CPI	chemical process industries
DOT	Department of Transportation
E&I	electrical and instrumentation
EPA	Environmental Protection Agency
ESD	emergency shutdown

FFS	fitness for service
FM	factory mutual research
FMEA	failure modes and effects analysis
FMECA	failure modes, effects, and criticality analysis
FTA	fault tree analysis
HAZMAT	hazardous material
HAZOP	hazard and operability
HI	Hydraulic Institute
IEC	International Electrotechnical Commission
IIAR	International Institute of Ammonia Refrigeration
IPL	independent protection layer
ISA	Instrumentation, Systems, and Automation Society
ISO	International Organization for Standardization
ITPM	inspection, testing, and preventive maintenance
LOPA	layer of protection analysis
MI	mechanical integrity
MOC	management of change
NB	National Board (of Boiler and Pressure Vessel Inspectors)
NBBPVI	National Board of Boiler and Pressure Vessel Inspectors
NBIC	National Board Inspection Code
NDE	nondestructive examination
NDT	nondestructive testing
NEC	National Electric Code
NFPA	National Fire Protection Association
OEM	original equipment manufacturer
OSHA	Occupational Safety and Health Administration
P&ID	piping and instrumentation diagram
PFD	probability of failure on demand
PHA	process hazard analysis
PM	preventive maintenance
PMI	positive material identification
PPE	personal protective equipment

ACRONYMS AND ABBREVIATIONS

PRV	pressure relief valve
PSM	process safety management
PSSR	prestartup safety review
PSV	pressure safety valve
PWHT	postweld heat treatment
QA	quality assurance
QC	quality control
RAGAGEP	recognized and generally accepted good engineering practice
RBI	risk-based inspection
RCA	root cause analysis
RCM	reliability-centered maintenance
RMP	risk management program
ROI	return on investment
RP	recommended practice
SCBA	self-contained breathing apparatus
SCE	safety-critical equipment
SHE	safety, health, and environmental
SIF	safety instrumented function
SIL	safety integrity level
SIS	safety instrumented system
SME	subject matter expert
TML	thickness measurement location
UL	Underwriters Laboratories Inc.
UPS	uninterruptible power supply
USCG	United States Coast Guard
UT	ultrasonic thickness

Examples of Industry RAGAGEP's

Oil Refining and Chemical Processing

Accidental Release Prevention Requirements - Risk Management Programs Under the Clean Air Act, U.S. Environmental Protection Agency's (EPA) standard, 40 CFR 68

API 510 – Pressure Vessel Inspection Code: Maintenance Inspection, Rating, Repair and Alteration; 8th ed., Addendum 1 - 12/98, Addendum 2 - 12/2000, Addendum 3 - 12/2001; and Addendum 4 – 8/2003; American Petroleum Institute (API)

API 570 - Piping Inspection Code, American Petroleum Institute, 2nd ed., 10/98, Addendum 1 - 2/2000, Addendum 2 - 12/01, Addendum 3 - 8/2003; API

API Recommended Practice (RP) 572 – Inspection of Pressure Vessels, 2nd Ed., 2001, API

API RP 574 – Inspection Practices for Piping System Components, 2nd Ed., 1998, API

API/(ANSI) Standard (STD) 521 – Pressure-Relieving and Depressuring Systems, 5th Ed., 2007, API

API RP 576 - Inspection of Pressure Relieving Devices, 2nd Ed., 2000, API

API RP 578, Material Verification Program for New and Existing Alloy Piping Systems, 1st Ed., 1998, API

API RP 752, Management of Hazards Associated with Location of Process Plant Buildings, 2nd Ed., 2003, API

API RP 579, Fitness-for-Service, 2000, API

API Publication 770, A Manager's Guide to Reducing Human Errors, Improving Human Performance in the Process Industries, 2001, API

ASME Boiler and Pressure Vessel Code, ASME

ASME B31.3 – Process Piping; ASME

Guidelines for Writing Effective Operating and Maintenance Procedures, CCPS

Guidelines for Mechanical Integrity Systems, CCPS

Guidelines for Engineering Design for Process Safety, CCPS

Guidelines for Process Safety Documentation, CCPS

Guidelines for Auditing Process Safety Management Systems, CCPS

Guidelines for Facility Siting and Layout, CCPS

Guidelines for Evaluating Process Plant Buildings for External Fires and Explosions, CCPS

Safe Design and Operation of Process Vents and Emission Control, CCPS

Plant Guidelines for Technical Management of Chemical Process Safety, CCPS

Guidelines for Investigating Chemical Process Incidents, 2nd Ed., CCPS

NFPA 25 - Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems, NFPA

Dow's Fire & Explosion Index Hazard Classification Guide, 7th Ed., AIChE

Chemical Engineer's Condensed Encyclopedia of Process Equipment, 2nd Ed., 2004, N.P. Chermisionoff

Atmospheric Relief, PowerPoint presentation, Bill Banick, ExxonMobil, October 24-25, 2006, 9th Annual Symposium, Mary Kay O'Connor Process Safety Center, Texas A&M University, College Station, Texas

Safety Bulletin Positive Material Verification: Prevent Errors During Alloy Steel Systems Maintenance, BP Texas City, TX Refinery Fire, October, 2006, U.S. Chemical Safety and Hazard Information Board (CSB)

Accident Investigations – A New Approach, 1983, National Safety Council

Ammonia Systems

B31.5-2001 Refrigeration Piping and Heat Transfer Components. (2001). Prescribes requirements for the materials, design, fabrication, assembly, erection, test, and inspection of refrigerant, heat transfer components, and secondary coolant piping.

ASME Boiler and Pressure Vessel Code. (2001). Provides requirements applicable to the design, fabrication, inspection, testing, and certification of pressure vessels operating at either internal or external pressures exceeding 15 psig. Contains mandatory and non-mandatory appendices detailing supplementary design criteria, nondestructive examination and inspection acceptance standards.

ANSI/ASHRAE Standard 15-2004. Safety Code For Mechanical Refrigeration.

ANSI K-61.1-1989 – American National Standard Safety Requirements for the Storage and Handling of Anhydrous Ammonia.

IIAR Process Safety Management Guidelines for Ammonia Refrigeration. (1998). Provides and overview of OSHA's Process Safety Management (PSM) Standard.

IIAR Ammonia Refrigeration Piping Handbook. Provides is a tutorial and reference book that represents the collective efforts of the most knowledgeable specialists in the ammonia refrigeration industry.

IIAR Ammonia Data Book. Features resource data essential for the safe and efficient operation of any ammonia refrigeration facility. Contains a revised chapter on US regulatory requirements for ammonia and other valuable compliance information about federal regulations, such as the Community Right to Know Act.

Oil Draining Guidelines. (1996). Describes procedures for safely draining oil from equipment.

American National Standard for Equipment, Design & Installation of Ammonia Mechanical Refrigerating Systems. (1999). Applies to closed circuit mechanical refrigerating systems using ammonia as a refrigerant. Contains information to specify equipment and machinery room design and installation for ammonia mechanical refrigerating systems.

IIAR Bulletin #R1. A Guide to Good Practices for the Operation of an Ammonia Refrigeration System. (1983). A reference document providing users of ammonia refrigeration with suggested practices for the operation of an ammonia refrigeration system.

IIAR Bulletin No. 107. Guidelines for: Suggested Safety and Operating Procedures When Making Ammonia Refrigeration Plant Tie-Ins. (1997, February). Addresses the need to approach ammonia refrigeration system tie-ins in a safe and methodical manner. Provides owners and contractors with a general checklist of safety and logistical items that should be reviewed when planning system shutdowns and tie-ins. Also provides engineers with ideas on how and where to design for future connections and taps that can make future tie-ins easier and safer.

IIAR Bulletin No. 108. Guidelines for Water Contamination in Ammonia Refrigeration Systems. (1986). Offers insights on where the water can come from and how to minimize continued infiltration. Provides an analytical approach to quantifying water concentrations, and recommends apparatus to remove the water.

IIAR Bulletin No. 109. Guidelines for IIAR Minimum Safety Criteria for a Safe Ammonia Refrigeration System. (1997, October). Embraces an IIAR goal of ensuring that ammonia refrigeration systems are engineered, constructed and operated in a safe manner. Provides detailed lists of items to consider when designing, inspecting, or operating a system. Housekeeping, recordkeeping, code considerations and personnel safety equipment are some of the safety issues addressed. Also provides inspection checklist forms for compressors, condensers, evaporators, vessels and heat exchangers to check system installation against recognized industry safety requirements.

IIAR Bulletin No. 110. Guidelines for Start-Up, Inspection, and Maintenance of Ammonia Mechanical Refrigerating Systems. (1993, March). Covers ammonia characteristics and hazards, inspection and maintenance of equipment, start-up issues, reference standards, safety equipment, and log book record-keeping.

IIAR Bulletin No. 111. Guidelines for Ammonia Machinery Room Ventilation. (1991, October). Major differences can be found between codes when determining ventilation requirements for ammonia machinery rooms. This bulletin cuts through the jargon and provides a practical ventilation design criteria that will satisfy existing code requirements and improve machinery room safety.

IIAR Bulletin No. 112. Guidelines for Ammonia Machinery Room Design. (1998, June). Summarizes generally accepted industry practice for ammonia machinery rooms, and references relevant codes and standards where instructive. The recommendations in this guideline are most applicable to completely new ammonia machinery rooms.

IIAR Bulletin No. 114. Guidelines for Identification of Ammonia Refrigeration Piping and System Components. (1991, September). Provides a comprehensive ammonia labeling scheme for companies in need of an identification system that "covers it all." Offers recommendations on label sizes, colors, installation locations and label material requirements.

IIAR Bulletin No. 116. Guidelines for Avoiding Component Failure in Industrial Refrigeration Systems Caused by Abnormal Pressure or Shock. (1992, October).

Identifies three significant factors that can lead to ammonia refrigeration system damage and personnel injury: trapped liquid, sudden liquid deceleration and vapor propelled liquid. Also explains the most likely causes for each of these problems and provides design, operation and servicing tips that can minimize the chances of them occurring. Offers numerous suggestions on making hot gas defrost operations safer and more effective.

EPA/CEPPO 550-F-98-017 (1998) – Hazards of Ammonia Releases at Ammonia Refrigeration Facilities.

EPA/CEPPO 550-F-01-009 (2001) – Hazards of Ammonia Releases at Ammonia Refrigeration Facilities (Update).

Chlorine

Chlorine Institute Pamphlets – The Chlorine Institute publishes a wide variety of publications geared for the chlorine industry. The Chlorine Manual is an American National Standard. Below is an example of some of the manuals or pamphlets available.

The Chlorine Manual 6th Edition

Pamphlet 63-First aid, medical, management/surveillance and occupational hygiene monitoring practices.

Pamphlet 65- Personal protective equipment for chlor-alkali chemicals.

Pamphlet 73- Atmospheric monitoring equipment for chlorine.

Pamphlet 82- Recommendations for using 100 and 150 pound chlorine cylinders at swimming pools.

Pamphlet 85- Recommendations for prevention of personnel injuries for chlorine production and use facilities.

Pamphlet 96- Sodium hypochlorite manual.

Pamphlet 151- Training guide for distribution and end-users of packaged chlorine.

Pamphlet 155- Water and wastewater operators' chlorine handbook.

Pamphlet 164- Reactivity and compatibility of chlorine and sodium hydroxide with various materials.

Pressure Vessels - RAGAGEP

TABLE 9-1
RAGAGEPs for Pressure Vessels

Issuing Organization	*Document*		*Application*
	Number	*Title*	
API	API 510	Pressure Vessel Inspection Code: Maintenance Inspection, Rating, Repair, and Alteration	Covers the maintenance, inspection, repair, alteration, and rerating procedures for pressure vessels.
API	Recommended Practice (RP) 572	Inspection of Pressure Vessels	Covers the inspection of pressure vessels.
API	ANSI/API 660 or International Organization for Standardization (ISO) 16812	Shell-and-Tube Heat Exchangers for General Refinery Services	Defines the minimum requirements for the mechanical design, material selection, fabrication, inspection, testing, and preparation for shipment of shell-and-tube heat exchangers.
ASME	ASME Code, Section VIII	ASME Boiler and Pressure Vessel Code (BPVC), Unfired Pressure Vessels	Provides requirements applicable to the design, fabrication, inspection, testing, and certification of pressure vessels operating at either internal or external pressures exceeding 15 psig.
NBBPVI	National Board (NB)-23	National Board Inspection Code	Provides rules and guidelines for in-service inspection of boilers, pressure vessels, piping, and pressure relief valves (PRVs). Also provides rules for the repair, alteration, and rerating of pressure-retaining items and for the repair of PRVs.

Pressure Vessels – Mechanical Integrity Activities

TABLE 9-13
Mechanical Integrity Activities for Pressure Vessels

New Equipment Design, Fabrication, and Installation		*Inspection and Testing*		*Preventive Maintenance*		*Repair*	
Activity	*Frequency*	*Activity*	*Frequency*	*Activity*	*Frequency*	*Activity*	*Frequency*
Example Activities and Typical Frequencies							
• Equipment specification, Vessel data sheet • Process design requirements • Materials selection • Vendor/Shop qualification • Equipment design by manufacturer • Design approval by owner • Welding/Quality control (QC) plan approval • Equipment fabrication • Inspection • Documentation preparation • Installation/ Commissioning • Acceptance and turnover	As required for fabrication and installation	External visual inspection	5-year maximum	• Activities identified from RCM or similar work planning initiatives, such as: • Routine visual surveillance • Process conditions monitoring/ tracking • Process performance monitoring	As required to meet preventive maintenance schedule or process monitoring needs	• Equipment replacement-in-kind • Unique vessel repair activities such as weld overlay, alterations, hot taps, or welding attachments to the pressure boundary • Painting • Insulation/Fireproofing repair • Chemical cleaning • Structural support and anchoring systems repair or renewal	As required by the condition of the equipment based on recommendations from ITPM activities or observations from normal operations
		Thickness measurement	½ corrosion life or 10-year maximum				
		Internal inspection or alternatively on-stream inspection (as applicable)	½ corrosion life or 10-year maximum, thickness measurement suffices if corrosion rate is less than 5 mils per year				
		Additional inspections for specific degradation modes (e.g., corrosion under insulation)	As required by condition of equipment and rate of degradation				

TABLE 9-13 *(Continued)*

New Equipment Design, Fabrication, and Installation	*Inspection and Testing*	*Preventive Maintenance*	*Repair*
Technical Basis for Activity and Frequency			
QA practices for pressure vessels	Scheduled with intervals set by the results of previous activity or at fixed intervals based on inspection code (API 510 or National Board Inspection Code [NBIC]) or jurisdictional requirements	Company or jurisdictional requirements	Performed when indicated by failure during normal operations or by the results of ITPM activities
Sources of Acceptance Criteria			
ASME PV codes for design and fabrication, in conjunction with more stringent requirements in company engineering standards and in facility-specific or jurisdictional requirements for the pressure boundary	Acceptance criteria from inspection codes API 510, NBIC, and/or jurisdictional requirements. Acceptance criteria for damage from specific degradation modes per API RP 579	Company requirements and good engineering practices, coupled with upper and lower safe limits for process conditions as defined in the process safety information (such as pressure, temperature, fluid composition, and velocity limits)	Design and fabrication codes: ASME PV codes, in conjunction with more stringent requirements in company engineering standards, or facility or jurisdictional requirements. In general, repairs and alterations are performed in accordance with ASME "R" stamp requirements
Typical Failures of Interest			
Incorrect material or weld metal, incorrect heat treatment, incorrect dimensions, misalignment or out-of-square flanges, leak during testing, weld defects, high hardness readings, use of unqualified welder or welding procedures	• Distortion of pressure boundary, leakage from cracks (e.g., fatigue, environmentally induced, stress corrosion cracking, caustic cracking), or holes in pressure boundary. Corrosion of pressure boundary, including corrosion under insulation • Lack of grounding, and excessive corrosion of structural support and anchoring systems	• Distortion of pressure boundary, leakage from cracks (fatigue or environmentally induced), or holes in pressure boundary. • Corrosion of pressure boundary, including corrosion under insulation. Lack of grounding, and excessive corrosion of structural support and anchoring systems	Incorrect material or heat treatment, incorrect dimensions, misalignment or out-of-square flanges, leak during testing, weld defects, high hardness readings, use of unqualified welder or welding procedures
Personnel Qualifications			
Company requirements and documented skills, NDE qualifications, inspection certifications or technical training for inspection and acceptance activities	Documented qualifications, industry inspection certifications (API 510 or NBIC), or specific technical training to analyze results	Tasks usually require craft-specific skills or operator-specific skills that are addressed within their respective training programs	Welders qualified per Section IX of the ASME Code. NDE technicians qualified in appropriate techniques. Industry inspection certifications (API 510 or NBIC) or specific technical training for pressure vessel engineering

TABLE 9-13 *(Continued)*

New Equipment Design, Fabrication, and Installation	*Inspection and Testing*	*Preventive Maintenance*	*Repair*
Procedure Requirements			
• Written procedures describing: • Engineering standards for specification of equipment • Project management (including hazard and design review schedules) • Vendor qualification • Documentation requirements • Project acceptance and turnover requirements	• Written procedures describing the inspection or test activity, including: • The manner, the extent, the location, and date the inspection or test is performed and by whom • The documentation and analysis of results • The resolution of functions or condition not meeting acceptance criteria	These activities generally do not require task-specific procedures	• Craft skill procedures for typical tasks encountered in repairs (e.g., welding, gasket installation, bolt tightening, pressure testing) • Job-specific procedures developed for repairs or alterations to the pressure boundary • Job-specific procedures for unique or complex repairs or jobs with specialized technical content (e.g., relraying, modifications to internals, catalyst handling) • Job-specific procedures with process engineering input for chemical cleaning
Documentation Requirements			
Company documentation requirements typically include U1 form, welding qualifications, design calculations, material certifications, QC results, heat treating records, as-built fabrication drawings, and nameplate rubbing	• Results and analysis of each inspection are documented for the life of the equipment • Inspection dates are tracked and technical deferral is required for late tests with alternate means of protection to be considered; deficient conditions are identified and resolved by the date recommended	Results are usually recorded by exception in equipment history files	Repair history is typically maintained with equipment inspection history

Atmospheric and Low-pressure Storage Tanks – RAGAGEP

TABLE 9-2
RAGAGEPs for Atmospheric and Low-pressure Storage Tanks

Issuing Organization	*Document*		*Application*
	Number	*Title*	
API	RP 575	Inspection of Atmospheric and Low Pressure Storage Tanks	Covers the inspection of atmospheric and low-pressure storage tanks designed to operate at pressures from atmospheric to 15 psig.
API	620	Design and Construction of Large, Welded, Low-pressure Storage Tanks	Covers the design and construction of large, welded, low-pressure carbon steel aboveground storage tanks, including flat-bottom tanks that have a single vertical axis of revolution. Applies to tanks with pressure in their vapor spaces at not more than 15 psig.
API	650	Welded Steel Tanks for Oil Storage	Covers the material, fabrication, erection, and testing requirements for aboveground, vertical, cylindrical, closed- and open-top, welded steel storage tanks. Applies to tanks with internal pressures approximating atmospheric pressure.
API	653	Tank Inspection, Repair, Alteration, and Reconstruction	Covers the inspection, repair, alteration, and reconstruction of steel aboveground storage tanks.

Process Piping Systems – RAGAGEP

TABLE 9-3
RAGAGEPs for Process Piping

Issuing Organization	*Document*		*Application*
	Number	*Title*	
ANSI	ANSI/ASME B31.3	B31.3 - Process Piping	Provides requirements for materials and components, design, fabrication, assembly, erection, examination, inspection, and testing of piping.
API	API 570	Piping Inspection Code: Inspection, Repair, Alteration, and Rerating of In-Service Piping Systems	Provides procedures for the inspection, repair, alteration, and rerating of metallic piping that have been in-service.
API	API RP 574	Inspection Practices for Piping System Components	Covers inspection practices for piping, tubing, valves (not including control valves), and fittings. This document is a supplement to ANSI/API 570.
NBBPVI	NB-23	National Board Inspection Code	Provides rules and guidelines for in-service inspection of boilers, pressure vessels, piping, and PRVs. Also provides rules for the repair, alteration, and rerating of pressure-retaining items and for the repair of PRVs.

Process Piping Systems – Mechanical Integrity Activities

TABLE 9-14
Mechanical Integrity Activities for Piping Systems

New Equipment Design, Fabrication, and Installation		*Inspection and Testing*		*Preventive Maintenance*		*Repair*	
Activity	*Frequency*	*Activity*	*Frequency*	*Activity*	*Frequency*	*Activity*	*Frequency*
Example Activities and Typical Frequencies							
• Design/fluid service requirements • Pressure rating • Materials selection • Fabrication contractor qualification • Design approval by owner • Welding/QC plan approval • Fabrication/storage/ shipping • Installation • Acceptance inspection and testing • Documentation preparation • Acceptance and turnover • Commissioning	As required for fabrication and installation	External visual inspection	Default interval values in API 570	• Activities identified from failure modes and effects analysis (FMEA) or other analysis techniques for RCM, risk-based inspection (RBI), or similar work planning initiatives • Process conditions monitoring/ tracking	As required to meet preventive maintenance schedule	• Piping/component replacement-in-kind • Commissioning activities • Temporary clamps • Hot taps/stopples, etc. • Painting • Insulation repair • Cleaning • Support, hanger and anchoring systems repair or renewal	As required by the condition of the equipment based on recommendations from the inspection and testing or preventive maintenance activities
		Thickness measurement inspection	Lesser of default interval values in API 570 or half-life based on measured wall thickness and calculated corrosion rates				
		RBI assessment	Adjustment of intervals and extent with RBI assessment, plan to be reviewed at default inspection intervals				
		• Special emphasis inspection • Injection point and soil-to-air interface	• Injection point inspection: Lesser of 3 years max. or half-life based on measured wall thickness and calculated corrosion rates • Soil-to-air interface inspection: default interval values in API 570				

TABLE 9-14 *(Continued)*

New Equipment Design, Fabrication, and Installation	*Inspection and Testing*	*Preventive Maintenance*	*Repair*
Technical Basis for Activity and Frequency			
Quality assurance practices for piping fabrication and installation	Scheduled with intervals set by the results of previous inspection or default maximum intervals listed in the inspection code (API 570)	Company or jurisdictional requirements	Performed when indicated by failure, by the results of 'preventive' maintenance activities, by the results of inspection and testing activities
Sources of Acceptance Criteria			
ANSI/ASME B31 codes for piping design and fabrication and in conjunction with more stringent requirements in Company Engineering Standards or facility-specific standards	Acceptance criteria from inspection code API 570 or jurisdictional requirements. Acceptance criteria for damage from specific degradation modes per API RP 579.	Upper and lower safe limits for process conditions, such as pressure, temperature, fluid composition, and velocity, as defined in the process safety information	ANSI/ASME B31 Design and Fabrication Code; in conjunction with more stringent requirements in Company Engineering Standards, facility, or jurisdictional requirements.
Typical Failures of Interest			
Dimensional errors, incorrect material or weld metal, incorrect dimensions, misaligned or out-of-square flanges, incorrect pressure rating for a component, leak during testing, weld defects outside of acceptance criteria, high hardness readings, use of unqualified welder or welding procedures	Leakage from cracks (e.g., fatigue, environmentally induced, stress corrosion cracking, caustic cracking), internal or external corrosion, corrosion under insulation, excessive vibration, unsupported or bound piping, permanent distortion, piping component not meeting pressure rating.	Process conditions exceed safe upper or lower limit	Dimensional errors, incorrect material or weld metal, incorrect dimensions, misaligned or out-of-square flanges, incorrect pressure rating for a component, leak during testing, weld defects outside acceptance criteria, high hardness readings, use of unqualified welder or welding procedure, leakage during hot tap/stopple operations, inability to remove hot tap/stopple machines
Personnel Qualifications			
Company requirements, and documented craft skills for installation, NDE qualifications, and ASME Section IX welding requirements for welders	Documented NDE qualifications, industry inspection certifications (API 570), or specific technical training for piping engineering for analysis of results.		Welders qualified per ASME Section IX Code, NDE technicians qualified to appropriate techniques, industry inspection certifications (API 570), or specific technical training for storage tank engineering.

TABLE 9-14 *(Continued)*

New Equipment Design, Fabrication, and Installation	*Inspection and Testing*	*Preventive Maintenance*	*Repair*
Procedure Requirements			
• Written procedures describing: • Engineering standards for specification of equipment • Project management (including hazard and design review schedules) • Vendor qualification • Documentation requirements • Project acceptance and turnover requirements	• Written procedures describing the inspection or test activity that includes: • The extent and location of the activity, how and when the inspection or test is performed, and by whom • How the results are documented and when the results are analyzed • How a function or condition not meeting the acceptance criteria is resolved		• Craft skill procedures for typical tasks encountered in repairs, such as welding, gasket installation, bolt tightening, etc. • Job-specific procedures developed for repairs or alterations to the pressure boundary • Job-specific procedures for unique or complex repairs, or jobs with specialized technical content, such as line lifting, hot taps, stopples, and clamp installations • Job-specific procedures with process engineering input for chemical cleaning
Documentation Requirements			
Company documentation requirements typically include welding qualifications, weld map, design calculations, material certifications, QC results, as-built drawings, and pressure test reports	• Results and analysis of each inspection are documented for the life of the equipment • Inspection dates are tracked and technical deferral required for late tests with alternate means of protection to be considered; deficient conditions are identified and resolved by the date recommended	Results are usually recorded by exception in the equipment history file	Repair history is maintained with equipment inspection history

Pressure Relief Devices – RAGAGEP

TABLE 9-4
RAGAGEPs for Pressure Relieving Devices

Issuing Organization	Document		Application
	Number	Title	
ANSI/ASME	ANSI/ASME B31.3	B31.3 - Process Piping	Provides requirements for materials and components, design, fabrication, assembly, erection, examination, inspection, and testing of piping.
API	API 510	Pressure Vessel Inspection Code: Maintenance, Inspection, Rating, Repair, and Alteration	Covers the maintenance, inspection, repair, alteration, and rerating procedures for pressure vessels used by the petroleum and chemical process industries. Also covers inspection and testing of pressure relief devices.
API	RP 520	Sizing, Selection, and Installation of Pressure-relieving Devices in Refineries, Part I - Sizing and Selection, Part II - Installation	Covers the sizing, selection, and installation of pressure relief devices for equipment that has a maximum allowable working pressure of 15 psig or greater.
API	RP 576	Inspection of Pressure Relieving Devices	Describes the inspection and repair practices for automatic pressure-relieving devices, including pressure safety valves (PSVs), pilot-operated PRVs, rupture disks, and weight-loaded pressure vacuum vents.
ASME	ASME B&PV Code, Section	ASME BPVC - Power Boilers	Provides requirements for all methods of construction and relief protection of power, electric, and miniature boilers, as well as high-temperature water boilers used in stationary service.
ASME	ASME B&PV Code, Section IV	ASME BPVC - Heating Boilers	Provides requirements for design, fabrication, installation, and inspection of steam generating boilers, and hot water boilers intended for low-pressure service that are directly fired by oil, gas, electricity, or coal. It also covers methods of checking safety valve and safety relief valve capacity.
ASME	ASME B&PV Code, Section VIII	ASME BPVC - Pressure Vessels	Provides requirements applicable to the design, fabrication, inspection, testing, and certification of pressure vessels operating at either internal or external pressures exceeding 15 psig. Also provides requirements for pressure vessel relief devices.
NBBPVI	NB-23	National Board Inspection Code	Provides rules and guidelines for in-service inspection of boilers, pressure vessels, piping, and PSVs. Also provides rules for the repair, alteration, and rerating of pressure-retaining items and for the repair of PSVs.

Pressure Relief Valves – Mechanical Integrity Activities

TABLE 9-15
Mechanical Integrity Activities for Pressure Relief Valves

New Equipment Design, Fabrication, and Installation		*Inspection and Testing*		*Preventive Maintenance*		*Repair*	
Activity	*Frequency*	*Activity*	*Frequency*	*Activity*	*Frequency*	*Activity*	*Frequency*
Example Activities and Typical Frequencies							
• Design requirements and process specifications • Component materials • Sizing design basis and sizing calculations • Vendor/shop qualification • Equipment design by manufacturer • Equipment fabrication • Inspection and testing • Documentation preparation • Installation and commissioning • Acceptance and turnover	As required for fabrication and installation	External visual inspection	Annual	• Activities identified from RCM or similar work planning initiatives, such as: • Routine visual surveillance • Process conditions monitoring/tracking	As required to meet preventive maintenance schedule or process monitoring needs	• Equipment replacement-in-kind • Mounting locations - repair or renewal • Piping conditions - internal restrictions • Visual inspection after the PSV operates	• 5 years, or to date stamped on the nameplate • As required by the condition of the equipment based on recommendations from ITPM activities or observations from normal operations • API RP 576
		Process conditions, including positions of upstream and downstream valves.	Weekly				
		Pop testing of pressure relief valve	As required by the service conditions				
		Inspection of inlet and outlet piping for fouling and plugging	Whenever the device is replaced or removed for testing				
		Additional inspections for specific degradation modes	As required by service conditions, condition of equipment, and rate of degradation				

TABLE 9-15 *(Continued)*

New Equipment Design, Fabrication, and Installation	*Inspection and Testing*	*Preventive Maintenance*	*Repair*
Technical Basis for Activity and Frequency			
QA practices for pressure relief valve fabrication, testing, and installation	Scheduled with intervals determined by the results of previous activities or at fixed intervals based on inspection codes (ASME, NBIC, or API RP 576) or jurisdictional requirements	Company or jurisdictional requirements	Performed when required by the qualification period for the device or as indicated by failure during normal operations or the results or ITPM activities
Sources of Acceptance Criteria			
• Codes and standards for design and fabrication of pressure relief devices (ASME BPVC- Section VIII, NB-23, NFPA 30, API RP 520, or other standards applicable for the specific application [e.g., ammonia, LPG]), in conjunction with requirements for pressure vessels • Company engineering standards, facility-specific and/or jurisdictional requirements	• Acceptance criteria from inspection codes (ASME, NBIC, or API) or jurisdictional requirements • Company standards for evaluating the condition of the device and process conditions	Upper safe limits for process conditions (pressure), company requirements, and good engineering practice for process conditions defined in the process safety information	• Design codes (ASME, NBIC, or API) • Company engineering standards, facility or jurisdictional requirements • Some jurisdictions require an ASME "VR" stamp for repairs
Typical Failures of Interest			
Incorrect materials or internal components, incorrect pressure rating for a component, weld defects outside of acceptance criteria, dimensional errors, misalignment or out-of-square flanges, leak during testing	• Leakage from the valve resulting from internal component fatigue, corrosion, leaking gaskets • Failing to open at set pressure • Plugging in the discharge piping by animals or water/ice resulting from loss of covers/flappers • Process valves closed that prevent the device from functioning • Fouling or pluggage of the vent header • Failure of the inert gas purge system	• Leakage from the valve caused by failure to reset after functioning • Process conditions in excess of the design criteria for the device • Fouling or pluggage of the vent header • Failure of the inert gas purge system	• Incorrect materials or internal components, incorrect pressure rating for a component, weld defects outside of acceptance criteria, dimensional errors, misalignment or out-of-square flanges, leak during testing • Leakage from the valve caused by internal component fatigue or leaking gaskets

TABLE 9-15 *(Continued)*

New Equipment Design, Fabrication, and Installation	*Inspection and Testing*	*Preventive Maintenance*	*Repair*
Personnel Qualifications			
• Manufacturer requirements, documented skills, inspection certifications, or technical training for inspection and acceptance activities during manufacture and installation • Training on the sizing, selection, and specification of relief devices in accordance with applicable codes and standards	Specific technical training on pressure relief valve inspection, testing, handling, and installation procedures	Specific technical training on pressure relief valve inspection, testing, handling, and installation procedures	Specific technical training on pressure relief valve inspection, testing, handling, and installation procedures
Procedure Requirements			
• Written procedures describing: • Engineering standards for specification of equipment • Project management (including hazard and design review schedules) • Vendor qualification • Documentation requirements • Project acceptance and turnover requirements • Proper installation requirements	• Written procedures describing the inspection or test activity including: • The manner, the extent, the location, and the date the inspection or test is performed and by whom • The documentation and analysis of results • The resolution of functions or conditions not meeting acceptance criteria	These activities generally do not require task-specific procedures	• Craft skill procedures for typical tasks encountered in repairs and replacements (e.g., gasket installation, bolt tightening, pressure testing) • Job-specific procedures developed for repairs or replacements
Documentation Requirements			
Company documentation requirements typically include manufacturer's data forms, design and sizing calculations, material certifications, initial pop test results, QC results, and device drawings	• Results and analysis of each inspection are documented for the life of the equipment • Inspection dates are tracked and technical deferral is required for late tests with alternate means of protection to be considered; deficient conditions are identified and resolved by the date recommended	Results are usually recorded by exception in the equipment history file	Repair history is maintained with equipment inspection history

Instrumentation and Controls (Safety Instrumented Systems SIS and Emergency Shutdown Devices ESD) – RAGAGEP

TABLE 9-5
RAGAGEPs for Instrumentation and Controls

Issuing Organization	Document		Application
	Number	Title	
API	RP 551	Process Measurement Instrumentation	Provides procedures for installation of the more generally used measuring and control instruments and related accessories.
API	RP 554	Process Instrumentation and Control	Covers performance requirements and considerations for the selection, specification, installation, and testing of process instrumentation and control systems.
API	API 555	Process Analyzers	Addresses the associated systems, installation, and maintenance of analyzers.
ASME	CSD-1	Controls and Safety Devices for Automatically Fired Boilers	Covers requirements for the assembly, maintenance, and operation of controls and safety devices installed on automatically operated boilers that are directly fired with gas, oil, gas-oil, or electricity, subject to certain service limitations and exclusions.
International Electrotechnical Commission (IEC)	IEC 61508-SER	Functional safety of electrical/electronic/ programmable electronic safety-related systems	Sets out a generic approach for all safety life-cycle activities for systems comprising electrical, electronic, and/or programmable electronic components that are used to perform safety functions.
ISA	ISA S84.01	Application of SISs for the Process Industries	Provides a safety life cycle and requirements for design, installation, and maintenance of SISs.
ISA	ISA-TR-84.00.02 Parts 1 through 5	Safety Instrumented Functions (SIFs) – Safety Integrity Level (SIL) Evaluation Techniques	This series covers the different evaluation techniques that can be used to determine if a specific SIS design satisfies the SIL requirements defined in the SIF.
ISA	ISA-91.00.01	Identification of Emergency Shutdown (ESD) Systems and Controls that Are Critical to Maintaining Safety in the Process Industries	Provides general requirements for determining safety-critical ESDs and controls, and for maintaining the identified instrumentation.
NFPA	NFPA 85	Boiler and Combustion Systems Hazards Code	Discusses the fundamentals, maintenance, inspection, training, and safety for the reduction of combustion system hazards.

Instrumentation and Controls (Safety Instrumented Systems SIS and Emergency Shutdown Devices ESD) – Mechanical Integrity Activities

TABLE 9-16
Mechanical Integrity Activities for SISs and ESDs

New Equipment Design, Fabrication, and Installation		*Inspection and Testing*		*Preventive Maintenance*		*Repair*	
Activity	*Frequency*	*Activity*	*Frequency*	*Activity*	*Frequency*	*Activity*	*Frequency*
Example Activities and Typical Frequencies							
Identification of materials of construction	When received	• Calibration of field devices (e.g., transmitters, switches) • Loop check • Functional test • Checking/running of logic solver diagnostics	As specified to meet the safety performance requirements	• Replacement of logic solver battery • Replacement/cleaning of logic solver, operator interface, and engineering interface cabinet air filters	Manufacturers' recommendations	• Troubleshooting • Replacement of field devices (e.g., transmitters, switches) • Replacement of logic solver, operator interface, and engineering interface cabinet components (e.g., integrated circuit boards	As required
		Calibration of field devices (e.g., transmitters, switches)	Before installation			Identification of materials of construction	When new devices are installed
		Visual inspection of field devices and installation	Initial installation				
		SIS loop check	Initial installation				
		SIS functional test	Initial installation				
		Manufacturer testing of logic solver, operator interface, and engineering interface	During fabrication				
		Factory acceptance testing of logic solver, operator interface, and engineering interface	Before delivery and again after delivery				

TABLE 9-16 *(Continued)*

New Equipment Design, Fabrication, and Installation	*Inspection and Testing*	*Preventive Maintenance*	*Repair*
Technical Basis for Activity and Frequency			
• API RP 554 • API RP 551 • ISA S84.01 and/or IEC 61508 • Manufacturers' recommendations • Industrial insurers' recommendations • Common industry practices	• API RP 554 • API RP 551 • ISA S84.01 and/or IEC 61508 • Manufacturers' recommendations • Industrial insurers' recommendations • Common industry practices	Manufacturers' recommendations	Common repair activity
Sources of Acceptance Criteria			
• Device specifications • SIS specifications • Manufacturers' recommendations • Industrial insurers' recommendations • Company engineering and/or maintenance standards	• Device specifications • SIS specifications • Manufacturers' recommendations • Industrial insurers' recommendations • Company engineering and/or maintenance standards	Manufacturers' recommendations	• Device specifications • SIS specifications
Typical Failures of Interest			
• Leakage, resulting from improper installation or materials of construction (e.g., incorrect gasket, incorrect metallurgy of wetted parts) • Failure to operate on demand caused by improper installation (e.g., incorrectly wired), incorrect configuration of control system, and/or incorrect calibration of the device • Potential ignition source or electrical shock to personnel as a result of improper installation • Improper electrical classification rating for the electrical classification of the area where the device is installed	• Failure to operate on demand or spurious trip of system as a result of wiring failure (e.g., loose connection, short), failure of input device (e.g., sensor electronic failure), or failure of controller/local solver (e.g., I/O card failure) • Failure to operate on demand or spurious trip as a result of an unauthorized change to controller/logic solver configuration and/or bypassing/forcing of the interlock/alarm	• Failure to operate on demand or spurious trip of system as a result of wiring failure (e.g., loose connection, short), failure of input device (e.g., sensor electronic failure), or failure of controller/local solver (e.g., I/O card failure) • Failure to operate on demand or spurious trip as a result of an unauthorized change to controller/logic solver configuration and/or bypassing/forcing of the interlock/alarm	• Leakage at process connection, resulting from improper installation or materials of construction (e.g., incorrect gasket, incorrect metallurgy of wetted parts) • Failure to operate on demand as a result of improper installation (e.g., incorrectly wired), incorrect configuration of control system, and/or incorrect calibration of the device • Potential ignition source or electrical shock to personnel as a result of improper installation • Improper electrical classification rating for the electrical classification of the area where the device is installed

TABLE 9-16 *(Continued)*

New Equipment Design, Fabrication, and Installation	*Inspection and Testing*	*Preventive Maintenance*	*Repair*
Typical Failures of Interest *(Continued)*			
	• Failure to operate on demand caused by isolation/plugging of input device connection or other process conditions (e.g., buildup on a temperature probe) that render input device inoperable or incapable of accurately measuring process conditions (e.g., pressure, temperature) • Potential ignition source if the device or connection shorts • Leakage at process connection as a result of overpressurization of the joint	• Failure to operate on demand caused by isolation/plugging of input device connection or other process conditions (e.g., buildup on a temperature probe) that render input device inoperable or incapable of accurately measuring process conditions (e.g., pressure, temperature) • Potential ignition source if the device or connection shorts • Leakage at process connection as a result of overpressurization of the joint	
Personnel Qualifications			
• Craft skills and knowledge required by the individual procedures • Training on the use and operation of special tools (e.g., signal simulators) required by procedures	• Craft skills and knowledge required by the individual procedures • Training on the specific procedures for the inspection and testing activities • Training on the use and operation of special tools (e.g., signal simulators) required by procedures	Craft skills and knowledge required by the individual procedures	• Craft skills and knowledge required by the individual procedures • Training on the specific procedures for the repair activities • Training on the use and operation of special tools (e.g., signal simulators) required by procedures
Procedure Requirements			
• Procurement and receiving procedures to ensure proper materials of construction • Device-specific testing, calibration, and installation procedures • Manufacturers' manuals • Special tool (e.g., signal simulator) use and operation procedures	• Written procedures describing the inspection or test activity, including: • The manner, the extent, the location, and the date the inspection or test is performed and by whom • The documentation and analysis of results • The resolution of functions or conditions not meeting acceptance criteria	• Written procedures describing the inspection or test activity, including: • The manner, the extent, the location, and the date the inspection or test is performed and by whom • The documentation and analysis of results • The resolution of functions or conditions not meeting acceptance criteria	• Generic written repair procedures for troubleshooting of SISs and replacement of integrated circuit boards that include references to the manufacturers' manuals • Device-specific installation procedures • Manufacturers' manuals • Special tool (e.g., signal simulator) use and operation procedures • Procurement and receiving procedures to ensure proper materials of construction

TABLE 9-16 *(Continued)*

New Equipment Design, Fabrication, and Installation	*Inspection and Testing*	*Preventive Maintenance*	*Repair*
Documentation Requirements			
• Vendor material of construction reports • Calibration record, including as-found and as-left conditions • Loop check sheet, including as-found and as-left conditions • Functional test record • Manufacturers' test report • Factory acceptance test report • Facility acceptance test report • Installation documentation to support pre-startup safety review (PSSR) requirements	• Calibration record • Loop check sheet, including as-found and as-left conditions • Functional test record • Diagnostic check sheet	• Completed/closed work order • Equipment PM record	• Completed/closed work order • Work order or storeroom records of parts/materials used • Return to service check sheet • Vendor material of construction reports

Pumps - RAGAGEP

TABLE 9-6
RAGAGEPs for Pumps

Issuing Organization	*Document*		*Application*
	Number	*Title*	
ANSI	ANSI/ASME B73.1	Specification for Horizontal End Suction Centrifugal Pumps for Chemical Process	Covers centrifugal pumps of horizontal, end suction single stage, centerline discharge design. Includes dimensional interchangeability requirements and certain design features to facilitate installation and maintenance.
ANSI	ANSI/ASME B73.2	Specification for Vertical In-Line Centrifugal Pumps for Chemical Process	Covers motor-driven centrifugal pumps of vertical shaft, single stage design with suction and discharge nozzles in-line. Includes dimensional interchangeability requirements and certain design features to facilitate installation and maintenance.
ANSI	ANSI/ASME B73.3	Specification for Sealless Horizontal End Suction Centrifugal Pumps for Chemical Process	Covers sealless centrifugal pumps of horizontal, end suction single stage, centerline discharge design. Includes dimensional interchangeability and features to facilitate installation and maintenance.
API	610	Centrifugal Pumps for Petroleum, Petrochemical, and Natural Gas Industries	Specifies requirements for centrifugal pumps, including running in reverse as hydraulic power turbines.
API	674	Positive Displacement Pumps - Reciprocating	Covers the minimum requirements for reciprocating positive displacement pumps.
API	675	Positive Displacement Pumps - Controlled Volume	Covers the minimum requirements for controlled volume positive displacement pumps.
API	676	Positive Displacement Pumps - Rotary	Covers the minimum requirements for rotary positive displacement pumps.
API	681	Liquid Ring Vacuum Pumps and Compressors	Defines the minimum requirements for the basic design, inspection, testing, and preparation for shipment of liquid ring vacuum pumps and compressors.
API	682	Pumps - Shaft Sealing Systems for Centrifugal and Rotary Pumps	Specifies requirements and provides suggestions for sealing systems for centrifugal and rotary pumps.

Pumps – Mechanical Integrity Activities

TABLE 9-17
Mechanical Integrity Activities for Pumps

New Equipment Design, Fabrication, and Installation		*Inspection and Testing*		*Preventive Maintenance*		*Repair*	
Activity	*Frequency*	*Activity*	*Frequency*	*Activity*	*Frequency*	*Activity*	*Frequency*
Example Activities and Typical Frequencies							
• Identification of materials of construction • Performance test • Pressure test	Initial fabrication	Visual inspection of sealing system	Each shift to weekly (depending on criticality)	• Bearing housing and/or gearbox oil/lubricant level check	Each shift to weekly	• Mechanical seal replacement • Pump disassembly and assembly	• As required
		Vibration analysis	• Continuous for pumps with large motors (e.g., 10,000 hp) • Weekly to quarterly (depending on criticality and horsepower)	• Changing of bearing housing and/or gearbox oil/lubricant	Manufacturers' recommendations		
Alignment	Initial installation and any time components are loosened, removed, or replaced	Performance testing	Depends on service conditions and criticality	Analysis of bearing and/or gearbox oil/lubricant	Monthly to semi-annually (depending on criticality and history)	Identification of materials of construction	When parts are received and/or at time of installation
Rotational check	Initial installation and any time the driver is connected	Swapping of redundant pumps	Weekly to monthly	Lubrication of metal couplings (e.g., Falk Steelflex, Fast gear, or similar types)	Manufacturers' recommendations		
Vibration analysis (baseline)	Initial startup	Operational/functional check of standby pump	Weekly to monthly	Internal inspection and rebuilding	As required, depending on history, service conditions, and criticality		

TABLE 9-17 *(Continued)*

New Equipment Design, Fabrication, and Installation	*Inspection and Testing*	*Preventive Maintenance*	*Repair*
Technical Basis for Activity and Frequency			
• Various codes, standards, or recommended practices from various organizations (e.g., API, Hydraulic Institute, ANSI, ISO) (application depends on industry and type of pump) • Manufacturers' recommendations • Common industry practices • Industrial recommendations	• Manufacturers' recommendations • Common industry practices • Industrial recommendations	• Manufacturers' recommendations • Common industry practices • Industrial recommendations	Common repair activity
Sources of Acceptance Criteria			
• Applicable code, standard, or recommended practice • Pump specifications • Manufacturers' recommendations • Company engineering and/or maintenance standards • Industrial insurers' recommendations	• Pump specifications • Manufacturers' recommendations • Company engineering and/or maintenance standards	• Manufacturers' and/or lubricant/oil vendor's recommendations • Company engineering and/or maintenance standards	• Pump specifications • Manufacturers' recommendation • Company engineering and/or maintenance standards
Typical Failures of Interest			
• Leakage from the seal/packing assembly as a result of improper installation or incorrect materials of construction • Inadequate flow/pressure as a result of improper assembly or improper installation of internal components (e.g., inadequate impeller clearance)	• Leakage from the seal/packing assembly as a result of overpressurization of the assembly, inadequate lubrication, bearing failure, or wear • Loss of, or inadequate, flow/pressure, resulting from failure of a drive component • Loss of, or inadequate, flow/pressure, resulting from failure, corrosion, erosion, or wear of an internal component (e.g., impeller)	• Leakage from the seal/packing assembly as a result of overpressurization of the assembly, inadequate lubrication, bearing failure, or wear • Loss of, or inadequate, flow/pressure, resulting from failure of a drive component • Loss of, or inadequate, flow/pressure, resulting from failure, corrosion, erosion, or wear of an internal component (e.g., impeller)	• Leakage from the seal/packing assembly as a result of improper installation or incorrect materials of construction • Inadequate flow/pressure resulting from improper assembly or improper installation of internal components • Leakage from pump casing as a result of improper assembly, installation, or materials of construction

TABLE 9-17 *(Continued)*

New Equipment Design, Fabrication, and Installation	*Inspection and Testing*	*Preventive Maintenance*	*Repair*
Typical Failures of Interest *(Continued)*			
• Leakage from pump casing as a result of improper assembly, installation, or materials of construction • Damage to seal/packing and/or associated equipment caused by excessive vibration	• Damage to pump casing from loose or broken internal component (e.g., impeller) • Damage to seal/packing and/or associated equipment caused by excessive vibration	• Damage to pump casing from loose or broken internal component (e.g., impeller) • Damage to seal/packing and/or associated equipment caused by excessive vibration	• Damage to seal/packing and/or associated equipment caused by excessive vibration
Personnel Qualifications			
• Craft skills and knowledge required by the individual procedures • Training on the specific procedures for the inspection and testing activities • Training on the use and operation of special tools required by procedures (e.g., laser alignment equipment)	• Craft skills and knowledge required by the individual procedures • Training on the specific procedures for the inspection and testing activities • Training on the use and operation of special tools required by procedures (e.g., vibration analysis equipment)	• Craft skills and knowledge required by the individual procedures • Training on the specific procedures for the preventive maintenance activities	• Craft skills and knowledge required by the individual procedures • Training on the specific procedures for the repair activities • Training on the specific procedures for the inspection and testing activities • Training on the use and operation of special tools required by procedures (e.g., laser alignment equipment)
Procedure Requirements			
• Procurement and receiving procedures to ensure proper materials of construction • Manufacturer testing procedures, including those for alignment tools • Pre-commissioning and/or commissioning testing procedures • Manufacturers' manuals • Pump alignment procedure • Pump installation procedure • Vibration analysis procedure • Vibration analyzer operation procedure and/or manufacturers' manual	• Written procedures describing the inspection or test activity including: • The manner, the extent, the location, and the date the inspection or test is performed and by whom • The documentation and analysis of results • The resolution of functions or conditions not meeting acceptance criteria	• Written procedures describing the inspection or test activity including: • The manner, the extent, the location, and the date the inspection or test is performed and by whom • The documentation and analysis of results • The resolution of functions or conditions not meeting acceptance criteria	• Generic written repair procedures for centrifugal pumps that include references to the manufacturers' manuals • Pump alignment procedure • Alignment tool (e.g., laser alignment) procedure and/or manufacturers' manual • Pump installation procedure • Procurement and receiving procedures to ensure proper materials of construction • Testing procedures covering operation of testing equipment and/or performance of nondestructive testing

TABLE 9-17 *(Continued)*

New Equipment Design, Fabrication, and Installation	*Inspection and Testing*	*Preventive Maintenance*	*Repair*
Documentation Requirements			
• Vendor material of construction reports • Nondestructive testing records • Performance and/or pressure test reports • Alignment report • Pump installation record • Vibration analysis data and report	• Inspection check sheet • Vibration analysis data and report • Performance test records	• Lube route check sheet • Completed/closed work order • Equipment PM record • Oil/lubricant analysis report	• Completed/closed work order • Work order or storeroom records of parts/materials used • Return to service check sheet • Alignment report • Pump installation record • Vendor material of construction reports • Nondestructive testing records
• Special notes: • Records retained for the life of the equipment • Installation documentation to support PSSR requirements	• Special notes: • Records retained as required by the facility's record retention policy • Documentation by exception may be acceptable (for certain tasks and select pumps)	• Special notes: • Records retained as required by the facility's record retention policy • Documentation by exception may be acceptable (for certain tasks and select pumps)	• Special notes: • Repair data (e.g., condition found, parts used, repairs made, condition left) are usually recorded in the equipment history files • Repair history retained for the life of the equipment

Compressors – RAGAGEP

TABLE 9-7
RAGAGEPs for Compressors

Issuing Organization	*Document*		*Application*
	Number	*Title*	
ANSI	ANSI/ASME B19.3	Safety Standard for Compressors for Process Industries	Covers the requirements for safety devices and protective facilities to help prevent compressor accidents as a result of excessive pressure, destructive mechanical failures, internal fires or explosions, and leakage of toxic or flammable fluids.
API	617	Axial and Centrifugal Compressors and Expander-compressors for Petroleum, Chemical, and Gas Industry Services	Covers the minimum requirements for centrifugal compressors that handle air or gas.
API	618	Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services	Covers the minimum requirements for reciprocating compressors and their drivers handling process air or gas with either lubricated or nonlubricated cylinders.
API	681	Liquid Ring Vacuum Pumps and Compressors	Defines the minimum requirements for the basic design, inspection, testing, and preparation for shipment of liquid ring vacuum pumps and compressors.

Turbines – RAGAGEP

TABLE 9-8
RAGAGEPs for Turbines

Issuing Organization	Document		Application
	Number	Title	
API	616	Gas Turbines for the Petroleum, Chemical, and Gas Industry Services	Covers the minimum requirements for open, simple, and regenerative-cycle combustion gas turbine units for services of mechanical drive, generator drive, or process gas generation.
API	611	General Purpose Steam Turbines for Petroleum, Chemical, and Gas Industry Service	Covers the minimum requirements for the basic design, materials, related lubrication systems, controls, auxiliary equipment, and accessories for general-purpose stream turbines.
API	612	Petroleum, Petrochemical and Natural Gas Industries - Steam Turbines - Special-purpose Applications	Specifies requirements and gives recommendations for the design, materials, fabrication, inspection, testing, and preparation for shipment of special-service steam turbines.

Fans and Gear Boxes – RAGAGEP

TABLE 9-9
RAGAGEPs for Fans and Gearboxes

Issuing Organization	*Document*		*Application*
	Number	*Title*	
API	673	Special Purpose Fans	Covers the minimum requirements for centrifugal fans intended for continuous duty.
API	613	Special Purpose Gear Units for Petroleum, Chemical, and Gas Industry Services	Covers the minimum requirements for special-purpose, enclosed, precision, single- and double-helical, one- and two-stage speed increasers and reducers of parallel-shaft design.
API	677	General-purpose Gear Units for Petroleum, Chemical, and Gas Industry Services	Covers the minimum requirements for general-purpose, enclosed, single- and multi-stage gear units incorporating parallel-shaft helical and right-angle bevel gears.

Fired Heaters and Furnaces – RAGAGEP

TABLE 9-10
RAGAGEPs for Fired Heaters and Furnaces

Issuing Organization	Document		Application
	Number	Title	
API	673	Special Purpose Fans	Covers the minimum requirements for centrifugal fans intended for continuous duty.
API	613	Special Purpose Gear Units for Petroleum, Chemical, and Gas Industry Services	Covers the minimum requirements for special-purpose, enclosed, precision, single- and double-helical, one- and two-stage speed increasers and reducers of parallel-shaft design.
API	677	General-purpose Gear Units for Petroleum, Chemical, and Gas Industry Services	Covers the minimum requirements for general-purpose, enclosed, single- and multi-stage gear units incorporating parallel-shaft helical and right-angle bevel gears.
API	535	Burners for Fired Heaters in General Refinery Service	Provides guidelines for selection and/or evaluation of burners installed in fired heaters.
API	560	Fired Heaters for General Refinery Service	Covers minimum requirements for the design, materials, fabrication, inspection, testing, and preparation for shipment for fired heaters.
API	RP 573	Inspection of Fired Boilers and Heaters	Covers inspection practices for fired boilers and process heaters (furnaces).

Fired Heaters and Furnaces – Mechanical Integrity Activities

TABLE 9-18
Mechanical Integrity Activities for Fired Heaters/Furnaces/Boilers

New Equipment Design, Fabrication, and Installation		*Inspection and Testing*		*Preventive Maintenance*		*Repair*	
Activity	*Frequency*	*Activity*	*Frequency*	*Activity*	*Frequency*	*Activity*	*Frequency*
Example Activities and Typical Frequencies							
• Heat or steam rate duty/fluid service requirements • Pressure rating • Materials selection • Fabrication contractor qualification • Design approval by owner • Welding/QC plan approval • Fabrication/storage/ shipping • Installation • Acceptance inspection and testing • Documentation preparation • Acceptance and turnover • Commissioning	As required for fabrication and installation	Inspection of heater or furnace firebox and tubes	Scheduled by user, usually in conjunction with planned unit shutdown or when an imminent failure condition is visible	• Activities identified from RCM or similar work planning initiatives, such as: • Process conditions monitoring/ tracking • Metal temperature monitoring • Water quality testing • Efficiency performance monitoring	As required to meet preventive maintenance schedule and boiler operating permit requirements	• Tube replacement • Burner replacement or repair • Insulation/refractory repair • Tube or piping support, hanger and anchoring systems repair or renewal • Commissioning activities following repair	As required by the condition of the equipment, based on recommendations from inspection and testing or preventive maintenance activities
		• Inspection of boilers, steam drums, tubes, and firebox • Waste heat boiler inspection • Hazardous waste incinerator inspection	Inspection schedule is not code derived, but is generally mandated by jurisdictional requirements	Decoking operations for heaters and furnaces	Performed when needed, based on performance and metal temperature data		

TABLE 9-18 *(Continued)*

New Equipment Design, Fabrication, and Installation	*Inspection and Testing*	*Preventive Maintenance*	*Repair*
Technical Basis for Activity and Frequency			
QA practices for equipment fabrication and installation	Jurisdictional requirements for boilers, and reliability issues for heaters and furnaces	Company or jurisdictional requirements	Performed when indicated by failure, or based on recommendations from preventive maintenance or inspection and testing activities
Acceptance Criteria			
• ASME and National Board codes for boiler design and fabrication, and installation • Company engineering standards, or facility-specific standards for heaters and furnaces	• Acceptance criteria from NBIC or jurisdictional requirements • Company standards for evaluating tube life and refractory damage	Upper and lower safe limits for process conditions defined in the process safety information, such as pressure, temperature, fluid composition, and velocity	• ASME and National Board codes for boiler repair • Company Engineering Standards, or facility-specific standards for heaters and furnaces
Typical Failures of Interest			
Incorrect material or weld metal, incorrect pressure rating for a component, leak during testing, weld defects outside of acceptance criteria, high hardness readings, use of unqualified welder or welding procedures, dimensional errors, incorrect refractory material, incorrect refractory installation or cure, incorrect spring hanger setting, damage to finned tube	Tube ruptures, tube bulging and distortions, creep damage, steam leaks, process fluid leaks, refractory failure, structural support failure	Process conditions, such as outlet temperatures, stack temperatures, combustion efficiency, heat input, flow balances, and tubular meal temperatures, exceed safe operating limit	Incorrect material or weld metal, incorrect pressure rating for a component, leak during testing, weld defects outside of acceptance criteria, high hardness readings, use of unqualified welder or welding procedures, dimensional errors, incorrect refractory material, incorrect refractory installation or cure, incorrect spring hanger setting, damage to finned tube
Personnel Qualifications			
• Boilers: ASME and National Board fabrication requirements • Heaters and furnaces: Company requirements, and documented craft skills for installation, NDE qualifications, and ASME Section IX welding requirements for welders	• National Board inspection certifications for boilers per jurisdictional requirements • Optional industry certifications (API 570, 510) or company-specific training for heater and furnace inspection	Company requirements for tasks	• Boilers: ASME and National Board fabrication requirements • Heaters and furnaces: Company requirements, and documented craft skills for repairs, NDE qualifications, and ASME Section IX welding requirements for welders, optional industry certifications (API 570, 510), or company-specific training for inspection of firebox piping

TABLE 9-18 *(Continued)*

New Equipment Design, Fabrication, and Installation	*Inspection and Testing*	*Preventive Maintenance*	*Repair*
Procedure Requirements			
• Written procedures describing: • Engineering standards for specification of equipment • Project management (including hazard and design review schedules) • Vendor qualification • Documentation requirements • Project acceptance and turnover requirements	• Written procedures describing the inspection or test activity, including: • The manner, the extent, the location, and the date the inspection or test is performed and by whom • The documentation and analysis of results • The resolution of functions or conditions not meeting acceptance criteria	• Written procedures describing the inspection or test activity, including: • The manner, the extent, the location, and the date the inspection or test is performed and by whom • The documentation and analysis of results • The resolution of functions or conditions not meeting acceptance criteria	• Craft skill procedures for typical tasks encountered in repairs (e.g., welding, gasket installation, bolt tightening) • Job-specific procedures for unique or complex repairs, or for jobs with specialized technical content (e.g., coil or tube replacement, new spring hanger settings, refractory repairs or burner adjustments) • Job-specific procedures with process engineering input for chemical cleaning
Documentation Requirements			
Company documentation requirements typically include: Manufacturers' data forms (boilers), welding qualifications, weld map, design calculations, material certifications, QC results, as-built drawings, and pressure test reports	Results and analysis of each inspection are documented for the life of the equipment	Results are usually recorded by exception in the equipment history file	Repair history is maintained with the equipment inspection history files

Switch Gear – Mechanical Integrity Activities

TABLE 9-19
Mechanical Integrity Activities for Switch Gear

New Equipment Design, Fabrication, and Installation		*Inspection and Testing*		*Preventive Maintenance*		*Repair*	
Activity	*Frequency*	*Activity*	*Frequency*	*Activity*	*Frequency*	*Activity*	*Frequency*
Example Activities and Typical Frequencies							
• Visual Inspection • Verification/testing of overcurrent protection	Initial installation	Visual inspection	• Monthly to quarterly (outdoor installations) • Quarterly to semiannually (indoor installation)	Overhaul of switch gear, including cleaning, inspecting, tightening, and adjusting of all components	3 to 6 years, depending on conditions	Removal and installation of circuit breakers	As required
		Infrared analysis	Annually to 3 years, depending on criticality, history, and starter size				
		Calibration and testing of protective relays; tripping of breakers; and testing insulation resistance of controls, meters, and protective devices	3 to 6 years, depending on conditions				
		• Inspection and maintenance of circuit breaker • Electrical testing of circuit breaker	3 years maximum (air-break and oil-immersed circuit breakers)				
		System testing of installed circuit breaker	After completion of circuit breaker electrical testing				
		Manufacturers' recommended inspection, maintenance, and testing of vacuum and gas-filled circuit breakers	Manufacturers' recommendations				

TABLE 9-19 *(Continued)*

New Equipment Design, Fabrication, and Installation	*Inspection and Testing*	*Preventive Maintenance*	*Repair*
Technical Basis for Activity and Frequency			
• NFPA 70 • Manufacturers' recommendations • Industrial insurers' recommendations • Common industry practices	• NFPA 70B • Manufacturers' recommendations • Common industry practices • Industrial insurers' recommendations	• NFPA 70B • Manufacturers' recommendations • Common industry practices	Common repair activity
Sources of Acceptance Criteria			
• NFPA 70 • Electric distribution system specifications • Manufacturers' recommendations • Industrial insurers' recommendations • Company engineering and/or maintenance standards	• Electric distribution system specifications • Manufacturers' recommendations • Industrial insurers' recommendations • Company engineering and/or maintenance standards	• Manufacturers'/vendor's recommendations • Industrial insurers' recommendations • Company engineering and/or maintenance standards	• Electric distribution system specifications • Manufacturers' recommendation • Company engineering and/or maintenance standards
Typical Failures of Interest			
• Failure to provide electrical power to safety-critical devices (e.g., controls) as a result of incorrect installation (e.g., incorrectly connected or improper sizing of the unit) • Potential ignition source or electrical shock to personnel as a result of improper installation or incorrect overcurrent protection device (e.g., incorrect fuse)	• Failure to provide electrical power to safety-critical devices (e.g., controls) as a result of failure of batteries, connection, transfer switch, and/or charging system • Potential ignition source or electrical shock to personnel as a result of a short in device or connection, incorrect overcurrent protection device (e.g., incorrect fuse), or operating equipment with extreme load (e.g., the operating temperature is too high)	• Failure to provide electrical power to safety-critical devices (e.g., controls) as a result of failure of batteries, connection, transfer switch, and/or charging system • Potential ignition source or electrical shock to personnel as a result of a short in device or connection, incorrect overcurrent protection device (e.g., incorrect fuse), or operating device with extreme load (e.g., the operating temperature is too high)	• Failure to provide electrical power to safety-critical devices (e.g., controls) as a result of incorrect installation (e.g., incorrectly connected or improper sizing of the unit) • Potential ignition source or electrical shock to personnel as a result of improper installation or incorrect overcurrent protection device (e.g., incorrect fuse)

TABLE 9-19 *(Continued)*

New Equipment Design, Fabrication, and Installation	*Inspection and Testing*	*Preventive Maintenance*	*Repair*
Personnel Qualifications			
• Craft skills and knowledge required by the individual procedures • Training on the use and operation of special tools required by procedures (e.g., electrical test equipment)	• Craft skills and knowledge required by the individual procedures • Training on the specific procedures for the inspection and testing activities • Training on the use and operation of special tools required by procedures (e.g., electrical test equipment)	• Craft skills and knowledge required by the individual procedures • Training on the specific procedures for the preventive maintenance activities	• Craft skills and knowledge required by the individual procedures • Training on the specific procedures for the repair activities
Procedure Requirements			
• Manufacturers' manuals • Electric distribution system installation procedures	• Written procedures describing the inspection or test activity including: • The manner, the extent, the location, and the date the inspection or test is performed and by whom • The documentation and analysis of results • The resolution of functions or conditions not meeting acceptance criteria	• Written procedures describing the inspection or test activity including: • The manner, the extent, the location, and the date the inspection or test is performed and by whom • The documentation and analysis of results • The resolution of functions or conditions not meeting acceptance criteria	• Generic written repair procedures for removal and installation of circuit breakers that include references to the manufacturers' manuals • Procurement and receiving procedures to ensure the use of proper equipment
Documentation Requirements			
• Record of overcurrent protection devices (e.g., fuse ratings) and settings • As-built drawings • Installation documentation to support PSSR requirements	Inspection and testing check sheet	• Completed/closed work order • Equipment PM record	• Completed/closed work order • Work order or storeroom records of parts/materials used • Return to service check sheet

Fire Protection Systems – RAGAGEP

TABLE 9-11
Summary of Commonly Used NFPA Codes for Fire Protection Systems

Fire Protection Systems	*NFPA Code*	
	Design and Installation Requirements	*Inspection, Test, and Maintenance Requirements*
Fire detection and alarm systems	NFPA 72	NFPA 72
Automatic sprinkler systems	NFPA 13	NFPA 25
Water spray systems	NFPA 15	NFPA 25
Foam-water sprinkler systems	NFPA 16	—
Foam systems	NFPA 11	NFPA 25
Standpipe and hose systems	NFPA 14	NFPA 25 and 1962
Fire pumps	NFPA 20	NFPA 25
Water supply systems	NFPA 22 and 24	NFPA 25
Fire hydrants	NFPA 24	NFPA 25
Portable fire extinguishers	NFPA 10	NFPA 10
Fire doors and dampers	NFPA 80 and 90A	—
Halon systems	NFPA 12A	NFPA 12A
Carbon dioxide systems	NFPA 12	NFPA 12
Clean agent systems	NFPA 2001	NFPA 2001
Dry chemical extinguishing systems	NFPA 17	NFPA 17
Buildings and structures	NFPA 101	NFPA 101

Selected Safety Equipment – RAGAGEP

TABLE 9-12
Summary of RAGAGEPs for Selected Safety Equipment

Safety Equipment	*Applicable Standard, Regulation, or Code*		
	ANSI	*OSHA*	*NFPA*
Eyewashes	ANSI Z358.1	29 CFR 1910.151 (c)	–
Safety showers	ANSI Z358.1	29 CFR 1910.151 (c)	–
Employee alarm systems		29 CFR 1910.165	NFPA 72
• Firefighting equipment • Protective equipment • SCBAs • Fire apparatus	ANSI Z88.2	29 CFR 1910.156	NFPA 600, 1851, 1911, 1915, 1971, 1981, and 1991
Respiratory protection equipment	ANSI Z88.2	29 CFR 1910.134	NFPA 1981 and 1991