

Safe Operation of Hydrofluoric Acid Alkylation Units

API RECOMMENDED PRACTICE 751
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Safe Operation of Hydrofluoric Acid Alkylation Units

1 Scope and Purpose

API 751 provides requirements (shall) and recommendations (should) for practices and procedures related to safety, operations, design, inspection, and maintenance to support the safe and reliable operation of Hydrofluoric acid (HF) alkylation units. Topics include hazard management; operating procedures and worker protection; materials, construction, inspection, and work practices; transportation and inventory control; pressure-relief, product treatment, and utility systems; and risk mitigation. This document contains requirements and recommendations that have been found effective based on broad industry acceptance, proven effective industry practices, testing, and regulatory requirements.

2 Normative References

The following documents are referred to in the text in such a way that some or all of their content constitutes the requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API 510, *Pressure Vessel Inspection Code: In-Service Rating, Repair, and Alteration*

API 570, *Piping Inspection Code: In-service Inspection, Rating, Repair, and Alteration of Piping Systems*

API Standard 653, *Tank Inspection, Repair, Alteration, and Reconstruction*

NOTE Whenever API standards are referenced, where equivalent national standards exist, they may be used in accordance with other applicable regulations for non-U.S. jurisdictions.

3 Terms, Definitions, Acronyms, Abbreviations, and Symbols

3.1 Terms and Definitions

For the purposes of this document, the following definitions apply.

3.1.1

acid detecting paint

Acid detecting paint is a durable, industrial coating with a unique acid-sensitive component, which changes color (e.g. golden yellow to brilliant red) when exposed to an acid or acid vapor of pH 3 or lower. (Also known as “acid indicating paint.”)

3.1.2

acid relief neutralizer

ARN

This system is where the flow from acid-containing relief valves is routed to allow the acid to be neutralized before being routed to the non-acid flare system. Vapor flow is typically routed to the general refinery flare header once neutralized. This can refer to a flare gas scrubber (FGS), a relief gas scrubber (RGS), or an acid relief neutralizer (ARN).

3.1.3

acid soluble oil

ASO

Typically seen as the waste stream created by secondary or side reactions in the presence of feed contaminants or unfavorable reaction conditions. Ranges from light to heavy material and will vary depending upon reaction conditions. This byproduct may be referred to as polymer.

3.1.4**bad actor**

An asset that experiences a history of issues causing concerns with continued mechanical integrity (e.g. an unusually short life cycle, unexpected short mean time between failures).

3.1.5**blistering (damage)**

A void, either at the subsurface or deeper, created in the metal due to molecular hydrogen (from re-combined hydrogen atoms) accumulating in laminations or other conducive sites in the steel. See 6.4.3.6 and G.2.1.2.

3.1.6**bolt**

An assembly of a nut(s) and a stud for fastening objects together.

3.1.7**caustic**

Refers to aqueous solutions of either sodium hydroxide (NaOH) or potassium hydroxide (KOH) that are both inorganic compounds and strong base materials.

3.1.8**cladding**

A metal plate bonded onto a substrate metal under high pressure and temperature whose properties are better suited to resist damage from the process than the substrate metal. (e.g. explosion bonded plate, roll bonded plate).

3.1.9**clamp**

An engineered mechanical enclosure applied to an asset, which meets design conditions, to prevent or contain a loss of containment of the pressure boundary.

3.1.10**coating**

A nonmetallic (inorganic or organic) material installed on the exterior or interior of an asset whose properties are better suited to resist damage from the atmosphere or process than the substrate material. (e.g. coal tar epoxy, external paint).

3.1.11**cold flow**

A load applied to an elastic material that will compress and deform it, allowing it to take up the irregularities between the two surfaces being sealed. The material may take on a permanent deformation or, in some cases, continue to deform. In a bolted joint, the compressed gasket creates the torque in the securing bolts, but as the gasket material creeps and the gasket thins, the bolts can relax, reducing the torque and loosening the joint (also known as gasket relaxation, gasket creep, viscoelastic creep).

3.1.12**condition monitoring location****CML**

Designated areas on pressure vessels and piping where periodic external examinations are conducted to directly assess their condition.

3.1.13**controlled deposition welding****CDW**

Any welding technique used to obtain controlled grain refinement and tempering of the underlying heat-affected zone (HAZ) in the base metal. Various controlled-deposition techniques, such as temper bead

(tempering of the layer below the current bead being deposited) and half bead (requiring removal of one-half of the first layer), are included.

3.1.14

corrosion control document

CCD

A document or other repository or system that contains the necessary information to understand materials damage susceptibility issues in a specific type of operating process unit at a plant site.

3.1.15

corrosion specialist

A person acceptable to the owner-operator who is knowledgeable and experienced in specific process chemistries, degradation mechanisms, materials selection, corrosion mitigation methods, corrosion monitoring techniques, and their impact on process equipment, including pressure vessels and piping systems and associated components.

3.1.16

corrosion under insulation

CUI

External corrosion of piping, pressure vessels, and structural components resulting from water trapped under insulation.

3.1.17

corrosion zone

Describes specific HF services that have similar corrosion characteristics and consequences in HF alkylation units (see G.3).

3.1.18

credible design point

This establishes a scenario basis for evaluating/constructing a toxic refuge shelter including the benefits derived from safety systems functioning as designed.

3.1.19

critical check valve

Critical check valves are those that need to operate reliably to avoid the potential for hazardous events or substantial consequences in situations where reverse flow may occur.

3.1.20

crossover line

A section of pipe on an HF trailer used to leak test the unloading hose or purge HF vapors from the hose before disconnecting.

3.1.21

dead-leg

Components of a piping system that normally have little or no significant flow. Some examples include blanked (blinded) branches, lines with normally closed block valves, lines with one end blanked, pressurized dummy support legs, stagnant control valve bypass piping, spare pump piping, level bridles, pressure-relieving valve inlet and outlet header piping, pump trim bypass lines, heat exchanger bypass lines, high-point vents, sample points, drains, bleeders, and instrument connections. Dead-legs also include piping that is no longer in use but still connected to the process.

3.1.22

decontamination

The removal of hazardous products from people, protective gear, or equipment.

3.1.23**delayed hydrogen cracking**

Cracking occurring in carbon or low-alloy (ferritic) steels, when molecular hydrogen has been entrapped as part of the welding process, embrittling the metal. This happens generally in the HAZ but could possibly extend into the weld metal. The cracks can form immediately after welding, a short time after welding (hours), or days afterwards. (Also known as “cold cracking” or “delayed cracking.”)

3.1.24**dilute HF acid**

A term used to designate a corrosion area of high-water concentration with some HF.

NOTE This term was used in earlier API 751 versions (Fourth Edition and earlier). It has been superseded by the defining of corrosion zones (as of the Fifth Edition) and is no longer used. It is maintained for reference only.

3.1.25**dilute HF in water corrosion zone**

The corrosion zone where the aqueous phase condenses, and contains a low concentration of HF in water (see G.3.5).

3.1.26**dispersion release plume**

This is the region affected by a potential release and is determined by dispersion modeling. Dispersion release plumes typically have varying shapes with a centerline concentration that progresses downwind.

3.1.27**dissimilar metal weld****DMW**

Signifying the weld that joins two metals of different compositions.

3.1.28**egress**

The act of exiting an area.

3.1.29**emergency stop system**

A system designed to stop the flow of HF acid during the unloading process.

3.1.30**equivalent industry standards**

Codes and standards accepted by the jurisdiction or locality (e.g. country, region) as having equally rigorous requirements and recommendations as those codes and standards referenced herein.

3.1.31**fractionator HF corrosion zone**

The corrosion zone between the bottom of the fractionator where HF is produced by thermal defluorination and the location where the HF and water in the fractionator feed is completely vaporized (see G.3.6).

3.1.32**fresh HF corrosion zone**

The corrosion zone where fresh HF acid is received, transferred, and stored (see G.3.2).

3.1.33**grounding/bonding cable**

A cable used to join two pieces of equipment together to eliminate the buildup of static electricity during the unloading process.

3.1.34**HF regeneration system**

The equipment in this system removes acid soluble oil (ASO), water, and other contaminants from the circulating acid. This system is referred to as the acid rerun or the acid regenerator.

3.1.35**HF service**

A process stream containing inorganic HF above de minimis concentrations during normal operations.

3.1.36**high residual element****high RE**

Carbon steel that does NOT meet the following criteria.

- For Base Metal: $\%C \geq 0.18 \text{ wt } \%$, $\%Cu + \%Ni \leq 0.15 \text{ wt } \%$.
- For Base Metal: $\%C < 0.18$ or unknown, $\%Cu + \%Ni + \%Cr \leq 0.15 \text{ wt } \%$.
- For Weld Metal: $\%Cu + \%Ni + \%Cr \leq 0.15 \text{ wt } \%$.

3.1.37**hot bolting**

Replacing bolts on flanges that are in service and under pressure.

3.1.38**hydrogen bake-out**

A heating procedure (time- and temperature-based) used prior to welding to drive hydrogen out of an asset manufactured from carbon steel and that is susceptible to atomic hydrogen dissolution and entrapment (derived from the process environment) in order to make it hydrogen-free, easily weldable, and less susceptible to hydrogen cracking due to the welding process.

3.1.39**injection point**

Injection points are locations where water, steam, chemicals, or process additives are introduced into a process stream at relatively low flow/volume rates as compared to the flow/volume rate of the parent stream.

3.1.40**inspection plan**

A documented set of actions and/or strategies detailing the scope, extent, methods, and timing of specific inspection activities to determine the condition of a specific piece of equipment.

3.1.41**inspection program**

A program that develops, maintains, monitors, and manages a set of inspection, testing, and preventative maintenance activities to maintain the mechanical integrity of equipment.

3.1.42**inspector**

A shortened title for an authorized pressure vessel, piping/piping component, or tank inspector qualified and certified in accordance with API 510, API 570, and API 653, respectively; not specifically assigned to the HF alkylation unit but may conduct inspection work within the boundary limits at the discretion of the owner-operator.

3.1.43**integrity operating window****IOW**

Established limits for process variables (parameters) that can affect the integrity of the equipment if the process operation deviates from the established limits for a predetermined length of time [includes critical, standard, and informational integrity operating windows (IOWs)].

3.1.44**licensor**

A business, organization, or individual who grants official (legal) permission to another entity (e.g. owner-operator) to make, do, operate, or own something the originator holds patent or ownership to.

3.1.45**lining**

A nonmetallic or metallic material installed on the interior of an asset whose properties are better suited to resist damage from the process than the substrate material (e.g. strip lining).

3.1.46**loss of primary containment****LOPC**

An unplanned or uncontrolled release of any material from primary containment, including nontoxic and nonflammable materials.

3.1.47**low-alloy steel**

A family of steels containing up to 9 % chromium and other alloying additions for high-temperature strength and creep resistance. The materials include C-0.5Mo, Mn-0.5Mo, 1Cr-0.5Mo, 1.25 Cr-0.5Mo, 2.25Cr-1.0Mo, 5Cr-0.5Mo, and 9Cr-1Mo. These are considered ferritic steels.

3.1.48**low residual element****low RE**

Carbon steel meeting the following criteria.

- For Base Metal: $\%C \geq 0.18 \text{ wt } \%$, $\%Cu + \%Ni \leq 0.15 \text{ wt } \%$.
- For Base Metal: $\%C < 0.18 \text{ wt } \%$ or unknown, $\%Cu + \%Ni + \%Cr \leq 0.15 \text{ wt } \%$.
- For Weld Metal: $\%Cu + \%Ni + \%Cr \leq 0.15 \text{ wt } \%$.

3.1.49**main acid**

A term used to indicate any service where a free HF phase is present or could be present due to condensation or entrainment during normal operation.

NOTE This term was used in earlier API 751 versions (Fourth Edition and earlier). It has been superseded by the defining of corrosion zones (as of the Fifth Edition) and is no longer used. It is maintained for reference only.

3.1.50**material verification program****MVP**

A documented quality assurance (QA) program used to assess metallic alloy materials (including weldments and attachments where specified) to verify conformance with the selected or specified alloy material designated by the owner/user.

NOTE This program may include a description of methods for alloy material testing, physical component marking, and program recordkeeping.

3.1.51**maximum credible event
MCE**

A hypothetical event that releases HF from among the HF-containing equipment on the alkylation unit and reaches the greatest downwind distance at a specified hazard endpoint. See K.2.2.

3.1.52**mechanical integrity**

The management of the activities necessary to ensure that equipment/assets are designed, fabricated, installed, operated, and maintained in a way that provides the desired performance in a safe, environmentally protected, and reliable fashion. Mechanical integrity is a subset of an effective reliability program and overall asset management, specific to equipment types, and more tactical in nature including the evaluation of condition requirements through regular monitoring and inspection of the condition of these assets.

3.1.53**mix point (mixing point)**

Mixing points are locations in a process piping system where two or more streams meet. The difference in streams may be composition, temperature, or any other parameter that may cause deterioration and may require additional design considerations, operating limits, inspection, and/or process monitoring.

3.1.54**modified HF
MHF**

A passive mitigation system whereby an additive to the HF acid is used to lower the acid volatility.

3.1.55**Ni alloy**

A family of metal alloy materials that the primary element is nickel (Ni). These are used because of their corrosion resistance. For HF units, the major alloy types that are used are nickel-copper (Ni-Cu) alloys (e.g. Alloy 400) and nickel-chromium-molybdenum alloys (e.g. Alloy C-276).

3.1.56**nondestructive examination
NDE**

The act of determining the suitability of some material or component for its intended purpose using techniques that do not affect its serviceability.

3.1.57**nontoxic refuge structure**

Buildings that are not a safe haven or a shelter-in-place. This can include administration buildings, maintenance buildings, and/or other buildings not needed for critical control activities.

3.1.58**on-stream inspection**

An inspection performed from the outside of a pressurized asset while it is operating using nondestructive examination (NDE) procedures to establish the suitability of the pressure boundary for continued operation.

3.1.59**phase change HF corrosion zone**

The corrosion zone where HF is either being condensed or vaporized, either by design or inadvertently. Phase change HF also occurs where a rich HF phase is either being absorbed into a liquid hydrocarbon stream or is forming by separating from a liquid hydrocarbon stream (see G.3.4).

3.1.60**piping specification break**

The location where the pipe specification changes to accommodate the piping design requirements, such as changing the material of construction, changing pressure rating, or changing temperature rating.

3.1.61**postweld heat treatment****PWHT**

A controlled process in which a material that has been welded is reheated to a temperature below its lower critical transformation temperature, and it then is held at that temperature for a specified period. A postweld heat treatment (PWHT) is performed to alleviate residual stresses, reduce hardness, and lower the risk of cracking.

3.1.62**potential hazard zone**

This is the reach of the centerline dispersion at a given concentration considered hazardous to human health regardless of wind direction. Potential hazard zones are typically circles; however, they can be strongly influenced by topography such as valleys, hills, or other dispersion modifiers.

3.1.63**pressure-relief valve****PRV**

A device used to protect equipment by reducing hazardous internal pressure before the equipment fails.

3.1.64**pressure testing**

A test performed on pressure vessels and/or piping that have been in service and that have undergone an alteration or repair to the pressure boundary(s). The test result will indicate whether or not the integrity of the pressure components is still compliant with the original construction code. The pressure test can be hydrostatic, pneumatic, or a combination thereof. Pressure tests at less than those specified by the construction code to determine if there may be leaks in the system are generally referred to as tightness tests.

3.1.65**pressure vessel**

A container designed to withstand internal or external pressure. This pressure may be imposed by an external source, by the application of heat from a direct or indirect source, or by any combination thereof. This definition includes heat exchangers, air coolers, columns, towers, unfired steam generators (boilers), and other vapor generating vessels that use heat from the operation of a processing system or other indirect heat source.

3.1.66**proactive initiator/instrument**

Also known as feed-forward control. A term describing an element or pathway within a control system that passes a controlling signal from a source in its external environment to a load elsewhere in its external environment. This is often a command signal from an external operator.

3.1.67**process hazard analysis****PHA**

An analysis designed to identify, safeguard, and mitigate potential process safety events.

3.1.68**purged**

To fill a piece of equipment with an inert gas to remove unwanted materials.

3.1.69**qualified**

Meeting the requirements and expectations of the owner-operator.

3.1.70**quality assurance****QA**

All planned, systematic, and preventative actions required to determine if materials, equipment, or services will meet specified requirements so that the asset will perform satisfactorily in service. Quality assurance plans will specify the necessary quality control (QC) activities and examinations.

3.1.71**quality control****QC**

Those physical activities conducted to check conformance with specifications in accordance with the QA plan (e.g. NDE techniques, hold point inspections, material verifications, checking certification documents, etc.).

3.1.72**rapid acid transfer system (RATS)****rapid acid deinventory system (RADS)****rapid acid dump system (RADS)****acid evacuation system (AES)**

A system designed to move the bulk HF acid inventory from the rich HF section into a safe location. See 9.6.3.

3.1.73**reactive initiator/instrument**

Also known as feedback control.

Feedback loops consider the system output and enable it to adjust its performance to meet the desired output response.

3.1.74**remotely activated valve**

An actuated valve designed, installed, and maintained for the primary purpose of achieving rapid operation.

3.1.75**residual element****RE**

The composition level of copper (Cu), chromium (Cr), and nickel (Ni) in carbon steel materials that can contribute to higher corrosion rates.

NOTE Formulas for calculation are provided in 6.2.2.1 and G.2.2.

3.1.76**rich HF**

Rich HF comes primarily in two forms—reactor acid and boot acid—and includes areas where a hydrocarbon stream contains residual amounts of entrained acid.

3.1.77**rich HF corrosion zone**

Areas of the unit where the HF phase is circulating through the unit at acid strengths generally over 80 wt % and is not being condensed, vaporized, or dropping out as a second liquid phase. See G.3.3 for further details.

3.1.78**Risk-Based Inspection
RBI**

A risk assessment and management process that is focused on the loss of containment of pressurized equipment in processing facilities, due to material deterioration. These risks are managed primarily through equipment inspection.

3.1.79**rundown**

Primarily product rundown systems that contain less than 1 ppm inorganic HF acid.

3.1.80**safe haven**

A building that has a specifically engineered design level of protection.

3.1.81**safety system**

Equipment and instrumentation that either protects against loss of containment of hazardous materials or mitigates the impact of a release that has occurred.

3.1.82**sample container**

A device used to obtain a sample of a process stream to assess the composition of the process stream.

3.1.83**shelter-in-place**

A building that gets additional isolation by the occupants closing doors, closing windows, and shutting off heating, ventilation, and air conditioning (HVAC) systems.

3.1.84**shelter-of-opportunity**

These are intended as a very short time shelter during an evacuation process. Examples include vehicle cabs, small storage sheds, and equipment enclosures. This is a shelter of last resort that may be used by occupants who unexpectedly find themselves inside a dispersion plume to provide a level of isolation between themselves and the ongoing dispersion.

3.1.85**small-bore piping**

Pipe or pipe components that are less than or equal to nominal pipe size (NPS) 2.

3.1.86**stainless steel**

Alloy steel containing 12 wt % or more Cr, so as to be resistant to rust and attack from various chemicals; may contain other elements to enhance corrosion resistance or physical properties; broken down primarily into ferritic, martensitic, austenitic, and duplex families.

3.1.87**stress corrosion cracking****SCC**

Progressive fracturing (e.g. crack formation) that occurs in metals as a result of the combined influence of tensile stress and a corrosive environment and that can lead to the unexpected sudden failure of normally ductile metal alloys.

3.1.88**strongback**

A mechanical device used to constrain the separation of damaged piping resulting from axial thrust loads on clamped piping components.

3.1.89**temporary repair**

A repair made to pressurized assets to maintain integrity and to continue safe operation until permanent repairs can be scheduled and accomplished within a time period acceptable to the inspector and/or engineer and applicable in-service mechanical integrity code.

3.1.90**tightness testing**

A test that is performed to ensure the overall leak tightness of the system or its connections before the process medium is introduced.

3.1.91**toxic refuge**

A structure designed to protect occupants from external hazards based on the credible design point scenario.

3.1.92**trace acid**

A term used to indicate only those process streams that contain primarily liquid hydrocarbons and any HF that is present is fully dissolved in the hydrocarbon.

NOTE This term was used in earlier API 751 versions (Fourth Edition and earlier). It has been superseded by the defining of corrosion zones (as of the Fifth Edition) and is no longer used. It is maintained for reference only.

3.1.93**turnaround**

A planned, scheduled shutdown of a unit or partial unit at the end of its normal operating cycle.

NOTE This time is used to perform routine cleaning, repairs, any special modifications, and inspections that cannot be done while the unit is in operation.

3.1.94**unit inspector**

In the context of API 751, this is the title for an authorized pressurized asset inspector qualified in inspection methods/techniques and certified in accordance with API 510 and API 570, who is responsible for the HF alkylation unit inspection program.

3.1.95**vent gas absorber****VGA**

This is a small heat exchanger located within the depropanizer overhead accumulator intended to condense HF vapors within the drum that decreases HF losses and neutralization demand in the downstream acid neutralization scrubber.

3.1.96**weathering area**

An area set aside with restricted access to let assets previously in HF service become neutralized through exposure to atmospheric conditions.

3.1.97**weld overlay**

A welding process where one or more layers of metal with specific characteristics are deposited to the surface of a base metal as a layer to impart desirable properties that are not inherent to the base metal or to restore the

original dimension of the component. In the former, this is completed to improve the corrosion, erosion, and/or wear resistance over the original base metal (also known as an overlay, weld overlay cladding, or hard facing).

3.1.98

wrap

A nonmetallic composite wrap is a temporary repair comprising two constituents: a fabric woven from a fiber (such as graphite) and a thermoset polymer (such as a two-component mix epoxy resin). A wrap may also be referred to as fiber-reinforced polymer (FRP) or a “polymeric wrap.” See 6.3.2.12 for further information regarding the use of wraps as a temporary repair.

3.2 Acronyms, Abbreviations, and Symbols

For the purposes of this document, the following acronyms and abbreviations apply.

ACGIH®	American Conference of Governmental Industrial Hygienists
ACFM	alternating current field measurement
AEGL	acute exposure guideline level
AHF	anhydrous hydrogen fluoride or anhydrous hydrofluoric acid
AIChE	American Institute of Chemical Engineers
AIHA™	American Industrial Hygiene Association
ARN	acid relief neutralizer
ASO	acid soluble oil
AWS	American Welding Society
BEI®	Biological Exposure Index
CCD	corrosion control document
CDW	controlled deposition welding
CE	carbon equivalent
CEMS	continuous emission monitoring system
CML	condition monitoring location
Cr	chromium
CTFE	polychlorotrifluoroethylene
CUF	corrosion under fireproofing
CUI	corrosion under insulation
Cu-Ni	copper-nickel (alloys)
Cu-Zn	copper-zinc (alloys, also known as brass alloys)

DMW	dissimilar metal weld
DOT	U.S. Department of Transportation
DP	differential pressure
DT	differential temperature
EIV	emergency isolation valve
EPA	U.S. Environmental Protection Agency
ERPG™	Emergency Response Planning Guidelines
FCAW	flux-cored arc welding
FCC	fluidized catalytic cracker
FEP	fluorinated ethylene propylene
FFS	Fitness-For-Service
FGS	flare gas scrubber
FTNIR	Fourier transform near-infrared technology
GMAW	gas metal arc welding
GTAW	gas tungsten arc welding
HAZ	heat-affected zone
HF	hydrofluoric acid or hydrogen fluoride
HIC	hydrogen-induced cracking
HSC-HF	hydrogen stress cracking in hydrofluoric acid
HVAC	heating, ventilation, and air conditioning
H ₂ S	hydrogen sulfide
IDLH	immediately dangerous to life and health
ICHMAP	Industry Cooperative Hydrogen Fluoride Mitigation/Assessment Program
iC ₄	isobutane
IOW	integrity operating window
KF	potassium fluoride
KOH	potassium hydroxide
LEPC	local emergency planning committee

LIBS	laser-induced breakdown spectroscopy
LOPA	layers of protection analysis
LOPC	loss of primary containment
LPG	liquid petroleum gas
MCE	maximum credible event
MDMT	minimum design metal temperature
MHF	modified HF
MSDS	material safety data sheet
MT	magnetic particle testing
MTR	material test report (mill test report)
MVP	material verification program
NaF	sodium fluoride
NaOH	sodium hydroxide
NDE	nondestructive examination
Ni	nickel
Ni-Cu	nickel-copper (alloys)
NPS	nominal pipe size
OES	optical emission spectrometer
PAUT	phased array ultrasonic testing
PEL	permissible exposure limit
PFA	perfluoroalkoxy
PHA	process hazard analysis
PMI	positive material identification
PPE	personal protective equipment
PQR	procedure qualification record
PRV	pressure-relief valve
PSM	process safety management
PT	penetrant testing

PTFE	polytetrafluoroethylene
PWHT	postweld heat treatment
QA	quality assurance
QC	quality control
RATS	rapid acid transfer system
RBI	Risk-Based Inspection
RE	residual element
RBV	remote block valve
REL	recommended exposure level
RGS	relief gas scrubber
RHF	rich hydrofluoric acid
RT	radiographic testing
RTJ	ring type joint
SAW	submerged arc welding
SCBA	self-contained breathing apparatus
SCC	stress corrosion cracking
SDS	safety data sheet
Si	silicon
SMAW	shielded metal arc welding
SME	subject matter expert
SOHIC	stress-oriented hydrogen-induced cracking
SOL	standard operating level
STEL	short-term exposure limit
SWUT	shear wave ultrasonic testing
TDL	tunable diode lasers
TEMA	Tubular Exchanger Manufacturers Association
TLV®	Threshold Limit Value
TWA	time-weighted average

UNS	Unified Numbering System
UT	ultrasonic testing
VGA	vent gas absorber
VT	visual testing (visual inspection)
WEEL™	Workplace Environmental Exposure Level
WFMT	wet fluorescent magnetic particle testing
WMT	wet magnetic particle testing
WPS	weld procedure specification
XRF	X-ray fluorescence

4 Hazards Management

4.1 Process Hazards Management Plan

4.1.1 General

Process hazards management applies to HF alkylation units. These units handle liquefied petroleum gas (LPG) and HF, which if released in quantity, may cause significant fire and toxic hazards. Each operating HF alkylation unit shall have a process hazards management plan. While the specific and detailed individual elements of the process hazards management plan may be located within overall refinery safety plans or emergency response documents, the HF alkylation unit should maintain a document that references these individual components to ensure quick and easy access to all unit personnel.

4.1.2 Process Hazard Analysis (PHA)

4.1.2.1 Overview

A PHA shall be conducted in all HF alkylation facilities. The permissible interval between PHAs shall meet applicable regulations. However, the maximum interval between analyses shall be 5 years. Once an initial PHA has been completed for the alkylation unit, each subsequent analysis may either be a revalidation of the previous analysis or a completely new analysis. More information can be found in Annex A.

4.1.2.2 Methods and Considerations

Many analytic techniques are available to the refinery owner-operator for evaluating process hazards. The PHA methodology selected shall satisfy applicable regulations.

Prior to initiating the PHA, the facilitator or other responsible party shall gather up-to-date process safety information for review by the PHA team, including the previous PHA reports, the implementation status of any previous PHA recommendations, and available industry incident experience. The PHA team identifies scenarios that could occur and evaluates the consequences of those scenarios. The PHA and associated risk management programs shall address routine and transient operations including:

- a) HF unloading and transfer;
- b) sampling;
- c) start-up;

- d) shutdown;
- e) upset and failure mechanisms, conditions, including mechanical integrity, that can result in an unintentional loss of HF or LPG, including losses to sewer effluent, product (such as propane, butane, and alkylate) streams, condensate, cooling water, and flare systems;
- f) human factors; and
- g) facility siting.

Upon completion of the PHA, the findings, recommendations, and any associated resolution shall be documented. The documentation shall include:

- a) a plan to resolve any recommendations in a timely manner, including interim measures if applicable;
- b) an implementation schedule;
- c) the identity of the individual(s) accountable and/or responsible for the resolution of any recommendations;
- d) the actions taken to resolve any recommendations; and
- e) the completion dates.

4.1.2.3 PHA Team

A team of qualified individuals to conduct the initial and any subsequent PHAs, at a minimum, shall include a facilitator, operator, and engineer [in addition, subject matter experts (SMEs) may be needed on an ad hoc basis] with experience and knowledge in the HF alkylation unit design and operations, including applicable standards, codes, specifications, health effects, and regulations. If the PHA team is lacking adequate support for any specific area of expertise, then the need for third-party resources should be considered.

4.1.3 Management of Change

In addition to the procedures required by applicable process hazards management regulations, any proposed change in controls, critical alarms, instrumentation, equipment, piping, operating limits, operating procedures, relief systems, safety systems, technology, safety mitigation systems, or facilities in an HF alkylation unit shall be subject to some form of management of change analysis. This shall include management of temporary equipment or piping installed on the HF alkylation unit, including for troubleshooting purposes. The management of change system shall also cover unit equipment installed and owned by third parties. Changes that have the potential to impact the mechanical integrity of a system should include a review by mechanical integrity personnel. Also, the refinery owner-operator shall review proposed changes to the organizational structure of the unit personnel prior to implementation to minimize the potential adverse impacts on the safety, health, and environmental performance of the HF alkylation unit.

4.1.4 Emergency Response and Control

4.1.4.1 General

Emergency response is one of three parts that work together for effective toxic chemical management (the other two parts are scenario development and toxic refuge design).

Each facility shall have written procedures for initiating an emergency response at the alkylation unit. These procedures should include the required actions of HF alkylation unit personnel, other refinery personnel, and external emergency services for initiating an emergency response or for responding to an emergency.

Each facility shall establish a written emergency response and control plan for each HF alkylation unit. The emergency response and control plan may be either a standalone document or incorporated into the overall refinery emergency response and control plan.

If the facility emergency response plans include the evacuation of occupied buildings or use evacuation alone (without the concept of toxic refuges), then an analysis of the scenarios from 4.1.5 should be completed to determine that a safe egress path exists for occupants of buildings near alkylation units. More information is available in Annex B.

4.1.4.2 Emergency Response and Control Plan Content

The emergency response and control plan shall include the following.

- a) For streams of HF and LPG, evaluation of the consequences of a potential HF release as well as evaluation of the consequences of the LPG release.
- b) Notification, interfaces, and expected response of external emergency services, including, but not limited to, police, fire, mutual aid, hospitals, and local emergency planning committees (LEPCs).
- c) The need for, and location of, emergency medical treatment for HF exposure, including the location of clinics and hospitals that are familiar with HF burn care.
- d) A system for communicating internally within the refinery and externally to the surrounding community on a response appropriate to the situation, e.g. evacuation or shelter-in-place.
- e) The frequency and methodology of testing of all communication systems.
- f) The scope and frequency of emergency response drills for LPG, HF-containing LPG, or HF releases.

In addition, the emergency response and control plan should address the following items.

- 1) The decision criteria to issue an evacuation or shelter-in-place instruction for the community. More information is available in Annex B.
- 2) Actions required to protect individuals within the toxic refuge (safe haven or onsite shelter-in-place buildings) for scenarios that potentially exceed the credible design point scenario. More information is available in Annex B.
- 3) How and when to evacuate buildings so that occupants who may be safer inside a toxic release shelter are not placed at greater risk by evacuating into a potential dispersion release plume pathway. More information is available in Annex B.
- 4) The need for or access to off-site emergency response equipment and emergency response personnel trained in handling HF and personal protective equipment (PPE) suitable for HF exposure.
- 5) Identify where the next available medical supplies are located and how to get them to the site if a credible design point scenario is exceeded (potentially more people impacted).
- 6) Identification of the number of HF medical kits that are needed for site occupants (inside the toxic refuge and outside on the units) based on the credible release scenario.
- 7) The potential for HF contamination in runoff water, including a strategy to manage the potential acidic runoff being sent to the refinery's wastewater system or off site.
- 8) The mechanism for assessing the condition of and decontaminating equipment, soil, buildings, and standing water inside and outside the alkylation unit after an HF release is over.

4.1.4.3 Emergency Response Team

The purpose of an emergency response team is to help establish on-site control of an HF alkylation emergency. Typically, this team is part of the refinery's general emergency response organization. Emergency response team criteria shall define minimum shift staffing levels.

Emergency response training specific to HF shall include, but not be limited to, physical and health hazards associated with HF, PPE (types, use, and limitations), medical response, decontamination, and heat stress.

4.1.5 Scenario Development

Scenario development is the second of three parts that work together for effective toxic chemical management (the other two parts are the emergency response and the toxic refuge design). More information is available in Annex B.

When managing toxics, there are often multiple independent layers of protection that are in place such that the frequency of larger releases has been minimized. Because of the cumulative effect of the independent protection layers, the design basis of toxic refuge may be based on a credible design point scenario vs a worst-case scenario. While there are many ways that a company/site can determine the credible design point scenario, the basis of the credible design point scenario used by the company/site should be written, documented, and incorporated into the emergency response plan. The credible design point scenario may be different for different buildings. More information is available in Annex B.

4.1.6 Toxic Refuge

4.1.6.1 Development and Selection of Credible Design Point Scenario for Toxic Refuge

Toxic refuge design is the third of three parts that work together for effective toxic chemical management (the other two parts are the emergency response and the credible design point scenario development). More information is available in Annex B.

A toxic refuge is designed to protect occupants from external hazards based on the credible design point scenario. As there are many different dispersion models that can calculate the concentration vs time profile at the toxic refuge, the dispersion model selected, as well as the dispersion model assumption basis, shall be documented.

Toxic refuges can be exposed to a range of potential scenarios.

Toxic refuges can be of varying designs and include various tightness levels. The tightness level is determined by measuring the air change rate of the building. The process of determining the actual air change rate can be completed using a technique such as ASTM E741-80, *Standard Test Method for Determining Air Leakage Rate by Tracer Dilution*. Safe havens are tighter buildings than shelter-in-place buildings and have a lower air change rate than shelter-in-place buildings.

4.1.6.2 Safe Havens

As safe havens can be of varying designs, including fresh air supplies for essential occupants at a minimum and scrubbing systems for air ingress points, engineering is involved in determining the suitability of the safe havens response for a given external release condition. If a site has a safe haven, then the design basis of the safe haven shall be documented. The safe haven design basis uses an external contaminant concentration and duration profile to determine the exposure level for occupants inside the building (or inside a particular designated area of the building) based on infiltration.

Safe havens can allow typical control functions to continue as occupants required to stay can bring a facility to a safer state. Safe havens can typically include elements of pressurization, supplied breathing air, door

airlocks, scrubbing systems, or duct isolation controls. A safe haven should have periodic testing to assure that the design features are in place and functioning to achieve the design basis.

In some situations, a building (or internal room) may be designated as a safe haven. For the defined credible release scenarios, these spaces provide adequate protection for personnel to perform critical control and operation functions. Safe havens have a specifically engineered design level of protection to prevent the migration of outside airborne contaminants from infiltrating these buildings while the occupants carry out operational activities. Written procedures shall be available to guide personnel in activating the safe haven mode. Equipment required to implement the procedures shall be maintained. A toxic concentration alarm in the safe haven (based on the credible design point scenario) should be installed. If an alarm is not installed, then a means for testing the atmosphere inside the safe haven shall be provided.

Written procedures for safe havens should include the following.

- a) Safe haven locations.
- b) Criteria and signals for enabling and ending safe haven status.
- c) Steps to secure safe havens against HF intrusion, such as HVAC shutdown and securing of external penetrations such as HVAC inlets and exhaust ductworks, vents, doors, and windows.
- d) A list of equipment to be maintained at each safe haven location, including communications equipment (radio, telephone), gas testing equipment, and materials for securing the safe haven.
- e) A process for periodically checking each safe haven location to ensure the equipment is being properly maintained and inspected.
- f) Criteria for drills on the use of safe havens. If the safe haven design intent is to protect the personnel who are located in the building when the incident starts (i.e. the building is on lockdown and personnel are not allowed to enter or leave) or if the intent is that external workers may enter these buildings in an emergency, then procedures to enter in an emergency should be included in the drills as well as verification that the design preference to enter and leave through airlock lobbies rather than emergency exits is achieved during the drill.

4.1.6.3 Shelter-in-Place Building

A building designated as a shelter-in-place building can also include supplies to allow the doors and windows to be taped to limit leakage around openings.

A difference between safe havens and shelter-in-place buildings is that safe havens have a designed air change per hour for the building (or portion of the building), while shelter-in-place buildings do not.

Where on-site buildings are used for shelter-in-place, written procedures shall be developed to guide personnel in entering and securing the shelters. Equipment required to implement the procedures shall be maintained. The procedures should include the following.

- a) Shelter-in-place building locations.
- b) Criteria and signals for entering and leaving shelter-in-place buildings.
- c) Steps to secure shelter-in-place spaces against HF intrusion, such as HVAC shutdown and sealing of doors and windows.
- d) A list of equipment to be maintained at each location, including communications equipment (radio or telephone) and materials for securing the shelter-in-place.

- e) A process for periodically checking each shelter-in-place location to ensure the equipment is being properly maintained.
- f) Criteria for drills on the use of shelters-in-place.

4.2 API 751 Audits

4.2.1 Comprehensive Audits of the HF Alkylation Unit Systems and Procedures

A comprehensive audit is a periodic review of a representative sample of the systems and procedures in place at an HF alkylation unit. To ensure that agreed-upon actions are resolved, management should establish a system to address the audit's findings and recommendations, document action item resolution, and communicate the findings and recommendations to appropriate personnel. Interim visits by select audit team personnel have been found to be effective in monitoring progress on audit findings.

An example comprehensive audit approach is provided in Annex C. The example approach provides elements that may be considered when an audit process is developed. Note that the list in Annex C is not to be considered exclusive or exhaustive in nature.

Each operating unit shall have a comprehensive written audit plan.

4.2.2 Frequency of Audits

Auditing allows an organization to systematically review its HF alkylation operations relative to the guidance of API 751 and to assess conformance with the organization's internal hazards management policies and procedures. Each operating unit shall be audited at least every 3 years.

4.2.3 Audit Plan Content

The audit plan should cover the safety, inspection, maintenance, hazard, and operability aspects of the HF alkylation unit.

The plan should identify, by title, the individuals responsible for carrying out the audit and should specify the appropriate HF alkylation unit experience for these individuals. The audit team should include representation from outside the facility such as one or more qualified individuals from other facilities within the same organization (such as corporate or sister refinery) or from an outside source.

The audit plan should provide a checklist specific to the HF alkylation unit including items such as those listed below (see Annex C for further details).

Auditors should review a representative sample of each of the following items, concentrating on the time period since the last audit.

- a) HF-related incident reports, including lessons learned and follow-up actions.
- b) Unit records, including operating procedures, logs, checklists, and operator training records.
- c) Equipment inspection and maintenance records.
- d) Training records for personnel who operate and perform work in the unit, including emergency response personnel.
- e) Mechanical and procedural changes in the unit.
- f) Testing and maintenance records and procedures for HF mitigation systems, including detection, monitoring, automatic control, water suppression, and rapid acid transfer system (RATS).

- g) Evidence of compliance with and understanding of established procedures from observation of and interviews with unit and plant personnel.
- h) Field inspection of the condition of alkylation unit equipment, including safety and mitigation equipment.
- i) Corrosion control document (CCD)/IOWs.

4.2.4 Audit Follow-up

All audit findings and recommendations shall be tracked and stewarded to resolution by the refinery owner-operator.

4.3 Environmental Impact

Operation of an HF alkylation unit generates waste material and byproducts that, because of their physical or toxicological properties, may require on-site processing prior to final disposition. To achieve this, procedures and facilities should be in place for the safe handling of these materials, both on site and off site, and comply with applicable environmental regulations. See Section 8 for additional information.

4.4 Lifting Over In-service Equipment

Use of a crane to lift materials or equipment and piping over piping and/or vessels that contain HF should be avoided. For all lifts over or potentially over HF-containing equipment and piping based on crane radius, a lift plan shall be prepared, documented, and reviewed. As such, lifts on adjacent units may need to be considered due to crane radius concerns. The lift plan shall include appropriate management approval as well as a consequence analysis that includes, at a minimum, assessing the radius of the lift from the start through the destination plus any additional area that could be affected as a result of failure or error. The lift plan shall include a written rigging plan and cover details such as alternative lifting schemes; placement, mechanical condition, and capacity of the crane; and location of underground piping, including sewer lines. If the lift is over or potentially over equipment and piping containing greater than 5 % HF based on crane radius, the lift shall require a plan review and approval by owner-operator leadership.

Synthetic slings should not be used unless concerns with chemical compatibility (with both HF and any neutralizing chemicals that may be used on the sling), service life, inspection, cleaning, and handling have been adequately addressed. ANSI/ASSP A10.42 addresses critical rigging activities over hazardous materials and gives examples. Appendix B of that document is especially helpful for lifting activities on HF alkylation units.

4.5 Incident Review

All visible HF vapor leaks including smoking or dripping, HF exposures, and potentially serious incidents shall be investigated.

The investigation should:

- a) evaluate the extent of the release and how detection and mitigation, including RATS, performed during the incident;
- b) identify the root causes;
- c) identify any detection and mitigation system deficiencies;
- d) identify any associated corrective actions;
- e) have a system in place to track corrective actions identified by the investigation team to resolution.

Procedures should specify the level of investigation to be conducted based on the severity of the event, the format and distribution of the investigation report, and the parties responsible for taking corrective action to prevent recurrences. For additional information, see API 585.

4.6 Security

Facility security plans shall be established based on site-specific considerations and comply with local and national regulatory requirements.

4.7 Safety Systems

Safety systems as described in this document consist of equipment and instrumentation that either protects against loss of containment of hazardous materials or mitigates the impact of a release that has occurred. Each site shall maintain a list of safety systems and equipment that designates device service and maintenance requirements for each. A backup power supply shall be provided for the critical electrically powered instruments and unit control systems. Fireproofing of cabling and components should be considered.

Work processes shall be in effect for testing these systems based on availability requirements needed for that service. The associated procedures should potentially include valve stroking, isolation and testing of primary elements and controls, and testing of critical pump auto start/stop systems in addition to system-specific recommendations listed below. The service history for these critical systems should also be maintained to assist the site in identifying and correcting problem areas. Any deficiencies noted in performance prior to or during testing should be noted in the test records and should be addressed by means such as increased testing/maintenance frequency or considering alternate designs.

Written procedures shall be in place describing how to maintain safe operations and respond to emergencies when a safety system is out of service for any reason, including equipment malfunction and bypassing for system testing.

Systems and equipment that are specific to HF alkylation units and shall be on the safety systems and equipment list include, but are not limited to, the following.

- a) Safety shower and eyewash station alarms.
- b) Key components of safety systems related to protecting against loss of containment due to HF intrusion in propane and butane rundown treatment systems.
- c) Breathing air system alarms.
- d) ARN caustic circulation system: flow.
- e) ARN caustic circulation: low temperature.
- f) HF levels: high acid boot level on the receiver upstream of the HF/propane stripper.
- g) Mitigation systems described:
 - 1) continuous HF release detection systems, including HF sensors and video surveillance equipment;
 - 2) key components of remotely activated and remotely controlled water mitigation systems;
 - 3) key components of the mitigation system that limit the duration of the event to the user-defined evaluation criteria, which may include:
 - i) rapid HF acid transfer systems,

- ii) remotely activated block valves for HF isolation;
- 4) other key systems identified as contributing to the overall mitigation system per the required quantitative assessment.
- h) Applicable emergency isolation valves (EIVs).

Testing of systems and equipment that are specific to HF alkylation units should include, but are not limited to, the following.

- a) All components of remotely activated and remotely controlled water mitigation systems as a whole to confirm it will work as designed.
- b) The rapid HF acid transfer systems as a whole system to confirm it will work as designed (such as when deinventorying acid in preparation for turnaround).

5 Operating Procedures and Worker Protection

5.1 General

Operating personnel at the HF alkylation unit play a key role in safe and reliable operation. They should be well informed, trained, and equipped. All personnel entering the HF alkylation unit can work safely if they follow the special requirements developed for this operation.

HF alkylation units shall have specific written operating procedures that address the toxic and corrosive nature of the HF catalyst. Because HF is not usually found in other operating parts of the refinery, some of the procedures are unique to the HF alkylation unit; therefore, special equipment and training are warranted.

5.2 Health Hazard Information

Pure anhydrous hydrofluoric acid (AHF) is a clear, colorless, corrosive liquid that boils at 67 °F. AHF can form a vapor cloud if released to the atmosphere and may behave like a dense gas traveling at ground level for a time before dispersing. It has a sharp, penetrating odor that humans can detect at very low concentrations in the air. It is completely soluble in water, forming HF solutions. In concentrated solutions, the HF fumes when exposed to air. While the HF in HF alkylation units is not pure or anhydrous, its physical properties and health effects are essentially the same as pure AHF.

Even brief contact with HF liquid or vapor can produce serious, painful chemical burns, sometimes with delayed onset. Large skin burns may be life-threatening. The vapor can be corrosive to the eyes, skin, and respiratory tract. Short-term exposure at higher concentrations can lead to serious health effects or death as a result of extensive respiratory damage. There may be chronic health effects, such as fluorosis, from repeated exposure.

ASO is a light-to-dark colored liquid that can contain varying concentrations of HF. Depending on its HF content, it may have a sharp, pungent, irritating odor. It is relatively insoluble in water. Contact with unneutralized ASO can produce serious, painful HF burns, sometimes with delayed onset.

Additional health hazard information may be available from the manufacturer or supplier of the material or within the safety data sheet (SDS) (previously known as material safety data sheet or MSDS).

Facilities shall comply with the requirements of worker protection health standards and regulations applicable to the facility's location. For example, OSHA 29 *CFR* Part 1910.1000 currently sets routine workplace exposure limits for HF exposure. Full-shift and/or task-based employee exposure monitoring/sampling shall be performed with the assistance of a qualified individual. Annex D provides examples of limitations and guidelines from multiple sources in effect at the time of publication. Definitions of terms and applications of limits or guidelines in Annex D should use regulatory or sponsoring professional organization sources. Users

of this recommended practice should consult the most recent edition of the source for each limitation or guideline for the most current information. Some local agencies may have more stringent requirements that should be consulted as applicable.

Facilities shall also comply with applicable hazard communication regulations. For example, OSHA 29 *CFR* Part 1910.1200 addresses labeling, SDSs, worker training, and recordkeeping requirements.

5.3 Plant Operations

5.3.1 Document Control

Unit documentation shall fall within a document control program. Unit documents should include procedures, operating manuals, training manuals, operating envelopes, sample schedules, and analysis performed on samples. The document control program should consist of the following elements.

- a) Approval process—procedures to review and approve documents, approval authorities by title/position.
- b) Review process—procedure for periodic review/re-validation, review approval authorities by title/position.
- c) Identification—title, date of issue, approver(s), revision number, designation as controlled/uncontrolled copy.
- d) External documents—identify external documents and control their distribution and utilization (e.g. OSHA regulations *CFR* 1910, API 751, ASTM metallurgy standards, etc.).
- e) Obsolete document management process—a procedure to identify, prevent improper use, and removal from the system if no longer needed.

5.3.2 Operating Manuals and Unit Documentation

5.3.2.1 General

Site and unit information and procedures shall be developed and made available to all assigned operating personnel of an HF alkylation unit. These documents shall be unit- and site-specific and shall, at a minimum, include the following.

- a) Descriptive information called for in applicable local process safety management (PSM) regulations and recommended practices.
- b) Site-specific emergency procedures including those for an HF release.
- c) Detailed HF exposure first aid procedures.
- d) HF sampling.
- e) Unit shutdown.
- f) Unit neutralization.
- g) Unit chemical cleaning.
- h) Unit dry-out and start-up.
- i) Unloading of fresh HF shipments.
- j) Operator unit surveillance.

The unit piping and instrument diagrams and appropriate electrical diagrams shall be accessible to operators, maintenance, and inspection personnel as required per their task.

Information on piping and equipment limitations should be readily available to operators. Other procedures are mentioned in the applicable sections of this recommended practice. An example of a procedure for unloading fresh HF is provided for reference in Annex I.

5.3.2.2 Specific Procedural Guidance

5.3.2.2.1 Removing Oxygen

Unit start-up procedures shall emphasize removing oxygen from the unit, with particular attention paid to high points such as vents, thermowell connections, pressure gauges, and dead-legs. Oxygen ingress into the unit during normal operations as well as after maintenance activities should be minimized.

5.3.2.2.2 Impulse Lines During Commissioning

The entire length of instrument impulse lines from the process equipment to the instrument should be flushed through several times during the dry-out phase of the unit start-up to remove traces of water, thus minimizing the potential for corrosion and plugging. For instruments and associated impulse line components that are susceptible to environmental cracking (e.g. Alloy 400), the entire length of the line from the process equipment to the instrument shall be purged through several times with an inert gas to remove any oxygen that might be present. These flushing operations during start-up are important, given the typical small line diameter and lack of flow under operating conditions.

5.3.2.2.3 Unit Dry-out

Due to the effects of high local water concentrations on carbon steel corrosion rates, start-up procedures shall include strategies to remove free water from the unit prior to the introduction of HF. Annex G.4.6.4 lists several means commonly used to do this.

5.3.2.2.4 Internal Regeneration

In some units, a slipstream of HF can be injected into the hot fractionation part of the plant to regenerate the HF (a practice known as "internal regeneration"). Internal regeneration should not be used if the circulating HF acid water content is $> 1\%$. If internal regeneration is used, the amount of this HF injection should not exceed the HF solubility in the hydrocarbon at the operating temperature to avoid the accelerated corrosion of carbon steel. See G.2.3 for more information.

5.3.2.2.5 Turnarounds

Written procedures shall be developed for preparing equipment for maintenance. These procedures should include steps for neutralization, purging, and isolation before the equipment is turned over to maintenance personnel. A corrosion specialist should be involved with planning the cleaning and neutralization process per the materials and inspection plan.

Temporary connections, fittings, and piping utilized for the draining and purging of the unit should be managed and coordinated between operations, maintenance, and inspection. Temporary connections and equipment should be dismantled and removed promptly after use. Procedures should be developed for the use of rod-out tools as described in 6.6.6.

Specific written procedures shall exist for preparing the HF alkylation unit for the turnaround that includes the shutdown, deinventory, purging/sweeping, neutralizing, and safely handing over the equipment for maintenance work. If HF acid is stored on the unit during a turnaround, a plan shall be developed to secure this inventory and prevent tampering with the vessel and associated equipment. All flanges and connections that remain in HF service during turnarounds should be made inaccessible to prevent inadvertent opening.

Special markings should alert the presence of acid and access to the area should be restricted. The area should be monitored, and mitigation equipment should be available in case of a leak.

Training of all turnaround personnel (including contractors) should include an emphasis on the location of any HF that is stored in the unit during the turnaround and the activities that are allowed and the activities that are prohibited in that area. Special care should be taken to avoid any maintenance work near or above the HF storage vessel that might disturb or damage the vessel or piping that contains HF.

5.3.2.2.6 Operations and Solids/Sludge

Units that have been neutralized and cleaned with a water-based cleaning agent can result in the presence of sludge and solids in piping and components that promotes under-deposit corrosion and fouling. Units or sections of a unit that are neutralized with anhydrous ammonia will generate large volumes of ammonium fluoride salts. Iron fluoride scale is generated from carbon steel piping components and accumulates during a normal run, in low-points, valves, areas of low flow, trays, tower internal parts, etc. The site should develop protocols to address the potential problems that iron fluoride solids and sludge create (examples include plugged relief-valve inlet lines, tower feed lines, low-point piping, check valves, instrumentation, etc.). Valves that are susceptible to scale buildup should be exercised on some frequency to prevent sticking. Regeneration systems with multiple feed legs should be alternated regularly to prevent plugging. Instruments can be supplied with flush [e.g. isobutene (iC4)] to sweep away scale and solids (see 6.6.8 regarding solids and sludge remaining after cleaning).

5.3.3 Operating Envelopes

Operating envelopes, which define and limit process, mechanical, safety, and environmental constraints for unit operation, shall be established and monitored and should address normal limits, acceptable limits, and critical limits.

Roles and responsibilities should be established to indicate responsible parties for:

- a) monitoring,
- b) reporting and notification,
- c) performing follow-up investigations, and;
- d) approving and implementing corrective actions,

Normal limits typically set the minimum and maximum, as required, for an ongoing stable and economical unit operation that is within the boundaries of acceptable and critical limits.

Acceptable limits, also known as integrity operating windows (IOWs), are used to minimize process parameter exceedances that may negatively impact the mechanical integrity of HF alkylation units (see 6.1.5 for requirements and recommendations on IOWs). IOWs for physical and chemical process parameters that could affect equipment integrity if not properly controlled shall be established for HF alkylation units. These limits should be set to ensure that unit operations do not present a concern to unit equipment or the environment. IOW limits should be established in accordance with recommendations within API 584. Additionally, a table of suggested IOWs is provided in G.5 of this document.

Critical operational limits shall be set to prevent any operation that could result in rapid damage to equipment integrity resulting in negative consequences to safety and/or the environment. Operation beyond these limits shall require immediate action to return the unit to acceptable conditions. Exceedances of critical limits should require a formal review to determine the cause and to provide corrective actions to minimize the likelihood of a repeat occurrence. Inspection and monitoring programs should be reviewed for adjustments to address equipment integrity concerns after exceedances in critical limits.

5.3.4 HF Sampling and Handling of HF-containing Samples

5.3.4.1 General

HF sampling and testing shall be completed on a frequency to ensure adequate control of HF quality (especially HF strength and water content) and proper calibration of the online HF analyzer (where applicable). Minimum sampling and testing frequency should be once per week with an online analyzer and three times per week without an online analyzer. Sampling of streams that contain potentially harmful quantities of HF require special precautions. Written procedures for HF-containing sampling shall be in place. These procedures should include sampling techniques, a diagram of the sampling manifold, PPE requirements, and communication of hazards.

5.3.4.2 Training for HF Sampling

Training shall be provided for all operating personnel who may collect or handle samples that contain or may contain HF. This training should include sampling techniques, PPE requirements, and communication of hazards.

5.3.4.3 Design of Sampling Stations

5.3.4.3.1 Location

HF sampling connections should be located at grade or on an unobstructed structure that permits easy egress for persons taking samples. A safety shower should be in close proximity to the sampling station.

5.3.4.3.2 Minimizing Exposure

Sampling systems for streams that contain HF shall be designed to minimize HF exposure to personnel. Sites should have a closed-loop flow through HF sampling system with flush and/or nitrogen purge capability and that, if vented, is vented to the acid flare.

A continuous online HF analyzer should be used to minimize the sampling frequency of the circulating acid.

5.3.4.3.3 Valves and Piping for HF-containing Sampling Stations

Sample points should be permanent installations that minimize the use of tubing and compression fittings. There has been a history of leaks on concentrated acid sample systems tubing and compression fittings due to oxygen-induced stress corrosion cracking (SCC) (see 6.5.6.6). Circulating acid sample cylinder connections should avoid quick connection fittings as they are more likely to become plugged or leak.

Any sample connections to the atmosphere and sewer vents shall have two block valves per connection including double isolation. When the connection is in use, both valves to the atmosphere/sewer should be closed. When the connection is not in use, all these double block valves should be closed, and the open end of the sample connection should be sealed or plugged. When sampling piping is not in use, it should be purged with unit flush or nitrogen, depressurized, and isolated.

5.3.4.3.4 Identifying Sample Points That May Contain HF

Sample points for streams that contain HF, as well as those that may contain HF in the event of a unit upset, shall be clearly identified in the field as potentially containing HF. Supply, return, and vent piping, if applicable, should be labeled.

5.3.4.4 HF-containing Sample Containers

Written procedures shall be established for the management of sample containers for streams that normally contain HF. The containers should be clearly and uniquely identified as being in HF service. These containers

should only be used for samples that contain HF. See 6.5.11 for the design and inspection of sample containers.

The written procedures for HF-containing sample containers shall include methods for neutralizing, cleaning, and storing the containers. External surfaces of sample containers should be neutralized and have residue removed prior to transporting from either the HF alkylation unit to the laboratory for analysis or returning from the laboratory to the HF alkylation unit post-analysis. External neutralization may be accomplished by submerging in a neutralization bath (e.g. soda ash, or equivalent) and/or spraying the exterior with a neutralizing solution and thoroughly wiping down, depending on the potential for sample contamination.

Sample cylinders that contain or may contain HF shall not be stored with sample cylinders that are in other services. The storage location for full sample cylinders in HF service awaiting laboratory analysis should be specifically designated and selected to minimize the potential for personnel exposure in the event of a leak in the cylinder (e.g. inside laboratory fume hood). After analysis, sample containers shall be purged of residual sample material prior to storing for later use.

5.3.4.5 Safe Transportation and Storage of Reactor Circulating HF Acid Samples

Procedures shall outline the site requirements for storage and transportation of the HF sample container used for sampling reactor circulating HF acid. If this sample is transported outside the battery limits of the unit, the sample container shall be placed in an outer container for transportation and that container shall be labeled to indicate that it is in HF service. The transportation container should have a means to visually determine if the cylinder is leaking prior to opening the transportation container. A good practice is painting the transportation container with HF detecting paint.

Safety and personnel exposure considerations shall be taken into account when establishing the transport route the sample takes to the testing location within the site laboratory. The sample should be placed in a well-ventilated restricted area until the actual testing of the HF can be performed.

5.3.5 Operations Response to HF Leaks

5.3.5.1 Operations Response to an Incipient HF Leak

A regular equipment monitoring program shall be in place to identify small HF leaks so that timely repairs can be made before they increase significantly. This program shall outline routine operator surveillance requirements and reporting for identified leaks. Procedures shall be in place for assessing and addressing leaks, including monitoring until the leak is permanently repaired. These procedures shall include written expectations for the timeliness of addressing leaks based upon their severity, inspection by an inspector within a defined timeframe based upon their severity, and a method of tracking each leak using a unique identifier. A visual cue (e.g. numbered tag at leak location) may be used for monitoring and awareness purposes. An example of a successful HF equipment leak monitoring program, including pictures of different levels of leak severity, is provided in Annex E.

Regular operator surveillance should include visual inspection (VT) of vessels, valves, piping connections, pressure gauges, instrumentation and associated tubing, pump cases, flanges, and seals. A checklist that includes remote or limited-access valves and instrument connections should be included in the program. Operators should be alert for such signs as acid detecting paint that has changed color, buildup of corrosion products between flanges, and the distinctive odor of HF. If transparent flange covers are used, the regular equipment monitoring program shall include routine observation through the covers for leakage and corrosion and allow rapid response to mitigate the leak and address bolting that has been exposed to HF. When transparent flange covers deteriorate and inhibit visual observation of the flange joint, they shall be replaced. The operating procedures should cover information pertaining to these surveillance techniques, including notification to the defined site responsible discipline for any acid detecting paint maintenance needs (see 6.5.13). All who enter the unit should receive sufficient instruction so that they are able to recognize and know how to report HF leaks.

5.3.5.2 Operations Response to a Beyond Incipient HF Leak

Operations shall have written procedures describing appropriate responses upon detection of all visible vapor HF leaks beyond smoking or dripping. The operating range of detection systems along with their alarm setpoints should be identified and included in these procedures. HF release response procedures should guide alkylation unit operations staff in the steps to be taken if an HF release occurs, including the following:

- a) accounting for all personnel in the unit;
- b) determining the source and magnitude of the leak;
- c) isolate leak, if possible;
- d) determining wind conditions and establishing potential impact areas;
- e) determining the extent of mitigation required;
- f) activating site-specific emergency mitigation systems and adjusting for maximum effectiveness (see Section 9);
- g) initiating site emergency response plans, as appropriate (see 4.1.4);
- h) implementing procedures for site personnel protection, as appropriate (see 4.1.4).

5.4 Laboratory Safety

5.4.1 Designated Area

Laboratories shall provide a designated area for storing, handling, and analyzing both HF samples and HF-containing samples such as iC4 recycle and ASO. The area should be designed to restrict entry by unauthorized personnel.

5.4.2 Fume Hood

Laboratories shall be appropriately equipped with a fume hood to prevent HF ingress into the lab. The fume hood shall be equipped with a face velocity indicating device and a low face velocity alarm. The fume hood's face velocity indicating device shall be routinely tested and the results documented. Fume hood and exhaust components and contents should be inspected annually for exposure to and degradation from HF and replaced as appropriate (see ANSI/AIHA Z9.5 and OSHA 29 CFR Part 1910.1450 for additional information).

5.4.3 HF Sample Testing Personal Protection Equipment

5.4.3.1 General

Written procedures shall be in place to cover the PPE requirements for the laboratory technician performing the HF testing. PPE shall include a minimum of upper body protection including arms, gauntlet type gloves (gauntlets are to cover the wrists when the arms are extended), face shield, and safety glasses with side shields. Laboratory PPE neutralization, cleaning, and testing procedures shall be consistent with the HF alkylation unit requirements.

5.4.3.2 Training for HF Laboratory on HF Sample Handling

Training shall be provided for all personnel who may handle or analyze samples that contain or may contain HF acid. This training should include handling techniques, PPE requirements, and communication of hazards. See 5.5.3.

5.5 Training

5.5.1 General

Refinery safety orientation materials should alert all people who enter the refinery to the presence of the HF alkylation unit, the demarcation of the unit, and the special training and PPE necessary to enter the HF alkylation unit.

A safety orientation to the HF alkylation unit shall be developed and communicated to all persons who work on or enter the HF alkylation unit. This orientation should address the hazardous nature of HF, including appropriate first aid procedures for HF exposure, location of HF-containing process equipment, PPE requirements, small HF leak recognition and reporting, and steps to be taken in the unlikely event of an HF release.

Because of the numerous issues associated with the compatibility of HF and various metals and chemical substances, a materials segment shall be included in the general HF orientation for those who will enter the unit. The intent of this training is to provide all who enter the unit with an understanding of the issues associated with the materials used in the unit and the ability to apply this information in their daily work practices. Annex G provides an overview of some of the metal and chemical compound issues associated with HF.

Additional HF alkylation specific training material should be developed and communicated to certain personnel as discussed in 5.5.2 to 5.5.4. Emergency response training specific to the HF alkylation unit is discussed in 4.1.4.3. A process should be in place to verify the training of any person entering the unit.

5.5.2 Training of Operators

Operating personnel shall be trained in the process, mechanical, and materials limitations of the HF alkylation unit, routine operating procedures, start-up, shutdown, emergency procedures, and mitigation systems. As systems for detection and mitigation of HF releases are unit-specific and may be complex, training on these systems should emphasize their operation and optimization as well as their proper care and maintenance (see 9.2).

5.5.3 Training of Maintenance, Engineering, Inspection, and Other Support Personnel

Employees and contractors working in the alkylation unit, as well as off-unit personnel that work on equipment that originated inside the unit, shall be trained on the procedures and safe work practices applicable to their jobs, including the hazards of HF. This includes but is not limited to maintenance, engineering, inspection, safety, and any other support personnel working in the unit. Those involved in maintaining the mechanical integrity of equipment in the HF alkylation unit shall be trained in the mechanical and materials limitations of the unit (e.g. carbon steel specifications, excluding stainless steels and silica, temperature limits, and special gaskets).

5.5.4 PPE Training

Training shall be provided for all personnel who enter or work in the HF alkylation unit or who are designated to respond to emergencies in the unit, in the use of applicable PPE and clothing. This training shall cover the explanation of each class of clothing, integrity checking of this equipment prior to donning, donning and removal steps, and cleaning procedures. Donning and removal steps should include hands-on training and physically putting on and removing a suit in front of trained personnel.

For those individuals that are expected to perform work that requires traditional Class D (OSHA "Level A") and traditional Class C (OSHA "Level B") suits, training shall include performing a simulated work task while wearing the suit. Those trained to use traditional Class D (OSHA "Level A") suits shall meet the fitness for duty medical recommendations of OSHA 29 *CFR* 1910.134(e) or alternate applicable local requirements.

5.6 PPE and Clothing

5.6.1 Availability and Written Policy

PPE shall be available for all personnel who work in or enter an HF alkylation unit for any reason. Each HF alkylation unit shall have a written policy that should outline requirements for use and training on protective equipment and clothing, including the potential health impact of using protective equipment under extreme ambient conditions. Heating and cooling systems for personnel who wear PPE in extreme working conditions are commercially available and should be considered.

5.6.2 Classes of PPE and Clothing

In selecting PPE for planned work activity, a combination of clothing and equipment should be chosen to conform to applicable regulations and to provide an appropriate level of protection without significantly impairing work performance. As conditions change, the level of protection should change in a way that is appropriate to the situation.

Levels of protection are typically divided into four classes. Traditionally, sites have designated “Class A” as the lowest level of protection and “Class D” as the highest. This classification system is widely used in the refining industry. However, many sites have adopted a lettering system that is similar to both the EPA and OSHA organizations. In this system, “Level A” is the highest level of protection and “Level D” is the lowest. This change in classification was adopted by these sites to reduce potential confusion if external responders are called into an event. The substantive criteria within each letter level may not be completely comparable between the industry and government schemes. Therefore, the table below should be used in the context of OSHA regulations on PPE and respiratory protection (see OSHA 29 *CFR* Part 1910.120, 132–136). Regardless of the classification used, the clothing classification nomenclature shall be clearly communicated to all site personnel and any external hazardous materials teams responding to an event.

Table 1 outlines the minimum requirements of the four classes of PPE for planned work activity, not for emergency response activity, from the highest level of protection to the lowest. Site-specific requirements or specific work tasks may call for additional PPE within a specified classification (e.g. the use of a neck cape for traditional Class A and Class B clothing).

Annex F outlines typical tasks that help define the need for clothing in each of the classes listed in Table 1.

Table 1—Minimum Requirements of the Four Classes of PPE for Planned Work Activity

Traditional Industry Classification	Closest Corresponding OSHA Level	Description	Use
Class D	Level A	— Totally enclosed chemical-resistant suit with self-contained breathing apparatus (SCBA) or with air-line-fed respirator with escape pack. — These suits should include provisions for positive remote communications, such as a radio inside the suit. — Option to consider new suits that provide flash fire protection.	Where exposure to HF vapor is expected and where there is potential for exposure to liquid HF. Direct contact with liquid HF should be avoided whenever possible.
Class C	Level B	— Air-supplied chemical-resistant hood or hood/ jacket combination. If a higher level of respiratory protection is needed, based on site-specific considerations and the type of work being performed, a positive-pressure SCBA or an air-line-fed respirator with an escape pack should be used under the chemical-resistant hood. — Chemical-resistant jacket and chemical-resistant overalls. — Chemical-resistant gauntlet type gloves sealed to the jacket sleeves. — Chemical-resistant rubbers/alky boots.	When low-level HF exposure is anticipated.
Class B	Level C	— Face shield. — Safety glasses with side shields or chemical splash goggles. — Chemical-resistant jacket and chemical-resistant overalls. — Chemical-resistant gauntlet type gloves (gauntlets are to cover the wrists when the arms are extended). Option to seal or attach the gloves to the jacket sleeves. — Chemical-resistant rubbers/alky boots.	For routine work on HF-containing equipment when no HF exposure is expected.
Class A	Level D	— Chemical splash goggles or face shield with safety glasses with side shields. — Chemical-resistant gloves. Optional chemical-resistant gauntlet type gloves (gauntlets are to cover the wrists when the arms are extended). — Chemical-resistant rubbers/alky boots or leather boots with chemical-resistant soles. — Optional chemical-resistant jacket.	When no physical contact with HF-containing equipment is to be made.

5.6.3 PPE Exceptions

Alkylation unit PPE policy should acknowledge the different types of special tasks involved in performing craftwork on the HF alkylation unit. In some cases, the hazards associated with the work require a different type of hand protection. For example, Insulators handle sheet metal with sharp edges that could cut through normal unit PPE and may require cut-resistant gloves.

Welders should be allowed to use welding gloves and hoods when working in the area. At times, crafts such as, instrument technicians, machinists, inspectors, and electricians are required to do very detailed work that can be cumbersome in traditional alky gloves. Nitrile or Viton^{® 1} type gloves offer protection against HF while improving the worker's dexterity. This glove option should be allowed for use by crafts requiring this type of detailed work.

Nitrile or Viton[®] gloves offer added HF protection under leather gloves for craftsmen such as insulators and welders. Nitrile or Viton[®] gloves are not durable and should be replaced if the gloves are damaged or are suspected of being damaged.

Procedures should be in place for proper care, cleaning, and handling of gloves and other PPE issued for special tasks on the alkylation unit.

5.6.4 Breathing Air

Breathing air shall meet the requirements for Grade D breathing air as defined in CGA G-7.1 or other applicable standards. Breathing air may be supplied from cylinders or a specially dedicated compressor. If a compressor is used, then a site assessment should be conducted to determine the appropriate monitoring of the air supply and for an emergency backup supply in case of compressor failure. The capacity of the breathing air system and how many workers it can support at one time shall be established and documented in unit procedures. Job work permitting and operator usage should not exceed breathing air capacity limits. See 4.7 for critical alarms associated with breathing air systems.

5.6.5 Backup Personnel for Non-emergency Situations

When work is performed that requires traditional Class C or D PPE (OSHA Level B or A) as described in 5.6.2, standby personnel shall be present, equipped with equivalent PPE, to assist the work party with egress from the work area for non-emergency situations. Note that per OSHA 29 *CFR* 1910.120(a)(3), "incidental release of hazardous substances where the substance can be absorbed, neutralized or otherwise controlled at the time of release by employees in the immediate release area, or by maintenance personnel are not considered to be emergency responses."

5.6.6 Multiple Storage Areas

Provision for an inventory of PPE in at least two different wind directions from the alkylation unit should be evaluated in the event that one location becomes inaccessible during an incident. In cold climates, heated storage areas should be considered for PPE.

5.6.7 Care, Cleaning, and Handling

Designated areas and facilities shall be provided for neutralizing, cleaning, and storing of all protective clothing. The facilities should be segregated into an HF-free or "clean" area where clean PPE is stored and donned and a contaminated or "dirty" area where used PPE is removed, neutralized, and cleaned.

Written procedures shall be established to remove, neutralize, and clean clothing and to prevent contamination of HF-free areas. Protective clothing should be neutralized and cleaned after each use per the

¹ This term is used as an example only and does not constitute an endorsement of this product by API.

manufacturer's suggested guidelines. Since protective clothing is chemical resistant, not HF proof, it should be washed and neutralized immediately after any contact with HF.

5.6.8 Inspection and Testing of PPE

All protective equipment, including new clothing, shall be inspected per the manufacturer's suggested guidelines before use. Procedures shall be developed for inspection and testing of protective clothing and equipment. Also, procedures shall provide criteria for removing the PPE from service if the results of the inspection and testing demonstrate the failure of that equipment. Removed equipment should be replaced to maintain minimum PPE stock on the unit as determined by the site. These procedures should be readily available for reference to the individuals using the clothing. Testing of gloves and inspection of boots shall be done before each use. The method for testing gloves shall be pressuring with air and immersing in water. Facilities should be available for the glove user to do this test.

5.7 Safety Showers and Eyewash Stations

Easily identifiable safety showers and eyewash stations shall be provided in the HF alkylation unit and other areas of the refinery where HF may be present (e.g. laboratory, shops). These showers and eyewash stations shall be located to provide timely and unrestricted access by personnel in the event of HF exposure. Control room and/or local alarms shall be provided to alert personnel when a safety shower or eyewash is activated and be designed to ensure immediate help is sent to the person using the shower or eyewash. Each shower shall be tested at a defined frequency, and the results of the tests shall be documented (see ANSI/ISEA Z358.1).

5.8 Controlled Access to the HF Alkylation Unit

5.8.1 Unit Demarcation

The HF alkylation unit shall be distinctively marked to avoid inadvertent entry onto the unit. Such markings should warn people that HF is present, that access is strictly limited and that special protective clothing is required. These markings should not prevent egress from the unit.

5.8.2 Unit Access and Work Permitting

All sites shall have in place a procedure to account for personnel entering the unit and to ensure that only people that have received the HF alkylation unit safety orientation (see 5.5.1) may enter. The procedure (e.g. sign-in/sign-out) should allow for the accounting of these individuals to be documented at a single location for quick reference.

A work permit shall be a prerequisite for maintenance work on the unit. The permit should describe the equipment to be worked on, the protective clothing required, and affirm that the equipment is properly prepared for work.

5.9 Medical Response to HF Exposure

5.9.1 General

Written procedures shall be established for medical response to HF exposure. The procedures should outline an appropriate response when personnel are exposed to HF vapor or liquid including inhalation, eye exposure, ingestion, or skin exposure. Symptoms of exposure and the critical role speed of response plays in minimizing the impact of HF exposure shall be included. HF first aid trained personnel should include operations and laboratory personnel to ensure appropriate speed of response. Training in HF first aid shall include an appropriate response for each type of exposure and be conducted on an annual basis, at a minimum.

On an annual basis, individual sites shall communicate and discuss preparedness with the local medical facility equipped to treat HF exposure. Procedures should include instructions on transportation to a medical

facility and appropriate communication with that facility. A knowledgeable employee should accompany the affected person to the medical facility to ensure that prompt treatment is provided. This employee can ensure that attending medical personnel are aware of the HF involvement and can furnish them with copies of any prearranged treatment plans.

Since HF can readily mix with and be retained by certain hydrocarbons (e.g. HF is contained in ASO and may be associated with fluoride scale found in alkylation unit equipment), personnel shall be trained to take precautions to avoid unprotected exposure to these materials.

5.9.2 First Aid

5.9.2.1 First Aid Kits

Suitably equipped HF first aid kits shall be readily available for use in HF alkylation units and other areas of the refinery where HF may be present or where HF exposure treatment may be given. First aid kit contents should be stored in a manner consistent with the manufacturer's guidelines. Established HF release emergency scenarios and availability of local backup medical resources should be considered when determining the quantity of HF first aid supplies immediately available to the refinery. Procedures shall indicate the number, location, content, and replenishment schedules and include a process for routinely checking the kits to ensure the contents are present and within their expiration date. Personnel should be designated to inspect the kits. All first aid kits should be equipped with tamper-evident seals and the seals verified to be in place on a routine basis.

5.9.2.2 Portable First Aid Kits

A portable first aid kit should accompany each affected individual being transported to off-site medical facilities.

Placement of additional portable first aid kits at the site of work should be considered during turnarounds or where work is taking place in enclosed, difficult to access areas.

5.9.2.3 Availability of Trained Personnel

HF first aid trained personnel shall be available on site during all shifts to quickly respond to the unit or laboratory in the event of an exposure. Established HF release emergency scenarios and availability of local backup medical resources should be considered when determining the number of trained on-site personnel per shift.

5.9.3 Follow-up Medical Treatment

The owner-operator should develop a prearranged plan for follow-up medical examination and treatment, as needed after initial first aid, at one or more nearby medical facilities. The plan should include written protocols for treatment of HF exposures, provision of protective equipment for facility personnel as needed, stocking of supplies for HF treatment, appropriate training, communication with refinery medical personnel, and procedures for hospital admissions that may be required after emergency treatment.

6 Materials, Fabrication, Inspection, and Maintenance Practices

6.1 Common Discussion about Section 6

6.1.1 Applicability and Organization of Section 6 and Annexes G/H

The materials, design, fabrication, repair, inspection, and maintenance guidance provided in Section 6 and Annex G and Annex H of this recommended practice are based on reported owner-operator experiences, testing, and evidence presented in industry forums. Usually, unexpected corrosion or deterioration can be

avoided by following the materials requirements and recommendations in this recommended practice and by maintaining unit conditions within properly specified process limits.

The Fifth Edition of API 751 was reorganized to conform to API style requirements for a publication. As such, in prior editions this section was known as “Section 3” and was associated with “Annex D.” With the current revision, this is now Section 6 and is associated with Annex G (corrosion and materials) and Annex H (inspection).

Further, Section 6 contains all the requirements and recommended practices for this subject matter. Annex G provides information on what equipment and piping belong in each corrosion zone, information on how materials perform in each zone, and descriptions of the types of damage that can be expected in each zone. Annex H provides information on the inspection practices specific to each zone or specific areas of concern (e.g. critical check valves). As such, Annex G and Annex H are intended to be used in conjunction with Section 6 to help establish inspection plans and help select appropriate materials of construction for components. Please note that while Annex G covers many of the corrosion mechanisms and materials in HF service, it may not cover everything that can or has occurred in any particular HF alkylation unit.

The owner-operator of each HF alkylation unit shall develop, implement, and maintain comprehensive inspection and maintenance programs that include written procedures aimed at monitoring and preserving the unit's mechanical integrity. Some sites have developed a single electronic repository referring to all the mechanical integrity guidance documents (e.g. local/company requirements, Section 6, Annex G, and Annex H) for easy access by all stakeholders. The repository may also include how the owner-operator adheres to the requirements and recommendations stated herein.

6.1.2 Corrosion Zone Terminology

The terms “trace acid,” “main acid,” and “dilute HF acid” have historically been used in previous editions of API 751 (Fourth Edition and prior, see Section 3 and Annex D). These terms have been discontinued in the Fifth Edition. These discontinued terms are defined in Section 3, Terms and Definitions. The previous editions could have been interpreted that all trace acid services have a similar risk (the combination of probability and consequence of failure) and that all main acid services also have similar risk, although different than trace acid service risk.

Since the likelihood of corrosion or other damage is higher in some areas, the combined probability and consequence of failure (i.e. risk) in all main or trace acid services are not the same, the HF alkylation unit has been redefined into services that are similar with respect to corrosion rates. The new categories are termed corrosion zones and are:

- a) fresh HF,
- b) rich HF,
- c) phase change HF,
- d) dilute HF in water,
- e) fractionator HF.

Annex G provides information on each corrosion zone.

6.1.3 API and ASME Codes and Standards Applicable to HF Alkylation Units

Equipment, including piping, used within HF alkylation units shall be designed and constructed to the appropriate ASME Codes or other applicable governing standards. For example, in the United States this would include ASME BPVC Section VIII for pressure vessels, ASME B31.3 for process piping, and API 520 for pressure-relief devices.

Additionally, API 510, API 570, and API 653 are the bases for inspecting, maintaining, altering, and repairing pressure vessels, piping, and storage tanks. Other applicable recommended practices (RPs) for equipment and piping, referenced by these codes, include but are not limited to:

- API 571 (for guidance on damage mechanisms),
- API 572 (for guidance on inspection),
- API 573 (for guidance on the inspection of heaters),
- API 574 (for guidance on the inspection of piping systems),
- API 575 (for guidance on the inspection of storage tanks),
- API 576 (for guidance on inspection and maintenance of pressure-relief devices),
- API 577 (for guidance on welding issues applicable to fixed equipment),
- API 578 (for guidance on material verification),
- API 579-1/ASME FFS-1 [for guidance on Fitness-For-Service (FFS) evaluations],
- API 580 [for guidance on Risk-Based Inspection (RBI)],
- API 582 (for guidance on welding),
- API 583 [for guidance on corrosion under insulation (CUI)],
- API 584 (for guidance on IOWs),
- API 585 (for guidance on investigating equipment failures),
- API 970 (for guidance on CCDs).

The content of the above documents will not be repeated herein except to note and emphasize issues that are specific to HF alkylation units. Also, where reference to an industry document is made within this section, it is implied in all cases the most recent edition of that document is to be utilized.

6.1.4 CCDs for HF Alkylation Units

Each HF alkylation unit should have a comprehensive CCD in accordance with API 970 or equivalent industry practice. The CCD should cover the credible damage mechanisms for each corrosion zone defined in this document.

6.1.5 IOWs for HF Alkylation Units

IOWs for physical and chemical process parameters that could affect equipment and piping integrity shall be established for HF alkylation units. An IOW program should be developed and implemented in accordance with API 584, including defining limits and appropriate responses to exceedances, to reduce the risk of loss of primary containments (LOPCs). IOWs are a subset of operating limits/windows covered in 5.3.3 and should be integrated with control systems that monitor those limits. Inspection plans and intervals are typically based on measured damage rates, which resulted from previous operating conditions and/or forecasted by corrosion specialists. Without an effective IOW program, process conditions that have changed or deviated from normal that could affect unit mechanical integrity or alter the effectiveness of the inspection plan may not be effectively communicated across all affected disciplines. Process upsets that result in temporary deviations (exceedances) outside of established IOW limits should be reported for review and possible follow-up by an

appropriate SME. Sustained or continued operation outside of IOW limits should only be authorized after a review of the hazards and risk of the proposed operation have been performed and approved and any changes to inspection and monitoring programs to address equipment and piping integrity/reliability have been implemented.

The owner-operator shall evaluate the IOWs listed in Table G.1 for inclusion in the site's IOW program, as appropriate. Annex G.5 provides a listing and rationale on the process variables that may need IOWs created and implemented. The owner-operator should also include any IOWs that are important to the mechanical integrity even if they are not identified in Table G.1. See API 584 for more information on the work process for establishing and implementing IOWs.

6.2 Materials of Construction

6.2.1 General

The principal materials of construction for HF alkylation units are carbon steel and nickel-copper Unified Numbering System (UNS) N04400 (Alloy 400) (e.g. Monel® 400 hereafter referred to as Alloy 400). Other materials, such as copper-nickel (Cu-Ni) alloys (e.g. UNS C71500, 70/30 copper-nickel) and nickel-base alloys [e.g. UNS N10276 (Alloy C-276) (e.g. Hastelloy® C-276 hereafter referred to as Alloy C-276) and UNS N10665 (Alloy B-2) (e.g. Hastelloy® B-2 hereafter referred to as Alloy B-2)], have been used in a limited number of selected applications.

Additional information and guidance on how materials perform in the various corrosion zones can be found in Annex G. Not all aspects of corrosion of these materials can be adequately addressed in this recommended practice. NACE 5A171 and MTI MS-4 provide overviews of materials performance in HF service.

Other limitations on specific materials and their use within an HF alkylation unit are also provided within this section.

6.2.2 Carbon Steel

6.2.2.1 Residual Elements (REs) in Carbon Steel

Corrosion rates on carbon steel are a function of carbon steel composition with respect to RE content as well as operating conditions. The presence of high-RE carbon steel components can affect corrosion rates in all corrosion zones and on all types of carbon steel, including welds. In dilute HF in water corrosion zones, the low-RE carbon steel components tend to corrode preferentially where connected to high-RE carbon steel components but not where low-RE carbon steel components are connected to each other. In the other corrosion zones, preferential corrosion of the entire component and/or localized corrosion may also occur on the high-RE carbon steel components. Regardless of RE content, localized corrosion may exist in all corrosion zones but may be more pronounced in the dilute and phase change corrosion zones.

Low-RE carbon steel should be used for new and replacement equipment and piping in all five HF corrosion zones where carbon steel is normally specified. When replacing individual components, the impacts of mixed RE components should be considered, especially in the dilute HF corrosion zone. Many ASTM specifications for carbon steel [such as ASTM A106, A333, A516, A960, or A961 (A105, A350)] include optional supplementary specifications for HF service (such as S9, S2, S54, S78, S62) that meet the recommended limits for RE content. If carbon steel meeting the RE requirements for HF service is not used or is unavailable, upgrading the metallurgy (typically to Alloy 400) or performing ongoing individual component thickness monitoring per 6.4.2.3.2 should be utilized. These RE requirements should also be applied to welds.

Low-RE materials shall meet the following criteria.

- a) For Base Metal: $\%C \geq 0.18 \text{ wt } \%$, $\%Cu + \%Ni \leq 0.15 \text{ wt } \%$.
- b) For Base Metal: $\%C < 0.18$ or unknown, $\%Cu + \%Ni + \%Cr \leq 0.15 \text{ wt } \%$.

c) For Weld Metal: $\%Cu + \%Ni + \%Cr \leq 0.15 \text{ wt } \%$.

A significant number of owner-operators have reported positive material identification (PMI)-measured RE does not always match the MTR. Because of this issue, using PMI to verify the RE content of carbon steel components and welds should be part of the material verification program (MVP). See 6.2.5 for recommendations and requirements regarding PMI and Annex G and Annex H for further information.

6.2.2.2 Hydrogen Damage of Carbon Steel

Carbon steel and HF react to form iron fluoride and atomic hydrogen. The atomic hydrogen from this reaction can diffuse into the steel and result in various forms of damage. These include blistering, hydrogen embrittlement, hydrogen stress cracking in hydrofluoric acid (HSC-HF), hydrogen-induced cracking (HIC), and stress-oriented hydrogen-induced cracking (SOHIC). HSC-HF, HIC, and SOHIC are forms of environmental cracking damage.

HSC-HF in HF service is typically managed by limiting hardness in carbon steel and welds. Blistering, HIC, and SOHIC base metal hydrogen damage is typically managed by specifying requirements for steel making cleanliness controls and PWHT. See 6.3.2.1 for further details.

6.2.2.3 Arsenic Contribution to Hydrogen Damage of Carbon Steel

Arsenic can promote hydrogen damage to carbon steel in all corrosion zones. Arsenic can enter the unit through fresh HF and/or unit feedstocks. See Annex I for recommendations and information on arsenic in fresh HF supplied by the vendor. The arsenic level in periodic batches of spent propane defluorinator solids should be tested to monitor the arsenic level the unit has been exposed to and to monitor for trends. Increasing arsenic levels increase the susceptibility to hydrogen damage, which may call for changes in inspection plans. See G.2.1.3 for further information.

6.2.3 Other Metallic Materials

6.2.3.1 Low-alloy Steels

Because of their high corrosion rates relative to carbon steel as well as their higher hardness and potential for HSC-HF services, low-alloy steels shall not be used in HF services. Most owner-operators have extended this to areas of the unit that are not normally in HF service but could be if another component either leaked or failed. Excluding low-alloy steels from the HF alkylation unit helps avoid incorrect material installation in HF service. See G.2.4 for further information on low-alloy steels.

6.2.3.2 Stainless Steels

Because of their high corrosion rates relative to carbon steel as well as their potential for fluoride stress cracking, stainless steels shall not be used in HF services, including temporary process hoses. An exception is the transportation and unloading hoses used in AHF and modified HF (MHF) services. This applies to all versions of stainless steel (ferritic, martensitic, austenitic, and duplex) and in all areas of the unit where HF is normally present, including samples that contain HF. This should be extended into areas that are not normally in HF service but could be in HF service during transitional operation (i.e. start-up, shutdown, upsets, or component failure). Some owner-operators prohibit the use of stainless steels inside the HF alkylation unit except for some specific locations.

Information on specific locations can be found in G.2.4. In addition, stainless steel in HF service shall not be used for:

- a) bolting on pressure boundaries, including instrumentation,
- b) pressure gauge bourdon tubes, even if a diaphragm seal and barrier fluid are used, or

- c) new or replacement components in seal flush systems for pumps regardless of design.

Existing seal flush systems on HF service pumps where stainless steel components are installed shall be evaluated for replacement with a more suitable metallurgy.

Materials selection and materials verification processes (including PMI) shall be in place for avoiding the installation of stainless steel components in HF services. See G.2.4 for further information on stainless steels.

6.2.3.3 Copper and Nickel Alloys

The combined presence of HF and oxygen can cause SCC of copper and nickel alloys and may also cause pitting and denickelification (see G.2.5). A program shall be in place to minimize the potential for SCC of equipment constructed of these alloys when there is a potential of simultaneous exposure to oxygen and HF.

The program should include the following elements.

- a) Procedures to neutralize the internal surfaces of equipment and piping that has been previously exposed to HF (e.g. placed in HF service) prior to performing any maintenance activities that may expose those surfaces to oxygen.
- b) Procedures to purge equipment to remove oxygen before placing equipment and piping in service and after any maintenance activities prior to exposing to HF (e.g. placing in HF service).
- c) Procedures to maintain a nitrogen purge on equipment that may not be neutralized and planned to be opened—to address oxygen ingress while idling a unit or portion of a unit.

Ni alloys (e.g. Hastelloy® C-276) can be used instead of Ni-Cu alloys (e.g. Alloy 400, Alloy K-500) to reduce the potential for SCC where simultaneous exposure to HF and oxygen is difficult to eliminate. If environmental cracking for Ni and Ni-Cu alloys is a potential, then heat treatment should be considered to reduce the risk of cracking when welded or cold-worked. See Annex G for a discussion of heat treatment temperature for welded components. Cu-Ni and Ni-Cu alloys shall not be used for pressure boundary bolting in HF services, including instrumentation, pumps, and valve bonnets in HF service.

Liquid metal embrittlement of Alloy 400 and Ni Alloys is known to occur when exposed to mercury. Units that may process mercury-containing feeds should evaluate the use of mercury-adsorbing materials as part of unit feed treating. Units that either run or potentially run mercury-containing feeds should set an upper IOW limit for refinery crude mercury content and/or the unit feed mercury content (G.5).

Although Ni alloys may be less susceptible to SCC than Alloy 400, they are not immune to it. Where Ni alloy components exist or are being planned for installation, the potential for environmental cracking at welds should be evaluated. If environmental cracking for Ni and Ni-Cu alloys is a potential, then heat treatment has been found to reduce the risk of cracking. See G.2.5.2 and G.2.7 for discussion of heat treatment temperature for welded components.

As Alloy 400 corrosion rates typically increase above about 300 °F (149 °C) in the presence of HF, process temperatures should be kept below this temperature. IOW limits should be considered for Alloy 400 equipment and piping operating at process temperatures close to or above 300 °F (149 °C). Thickness inspections should be carried out at increased frequency if temperatures are close to or exceed 300 °F. In addition, IOWs should be set for limiting process temperatures in the HF regeneration section of the unit.

Alloy K-500 may be used for high-strength applications such as relief valve springs, pump shafts, valve stems, and bellows, etc. When used in these applications, the material hardness of Alloy K-500 should not exceed HRC 30 to reduce the potential for SCC.

Because of embrittlement and sensitivity to velocity-assisted corrosion, copper-zinc (Cu-Zn) alloys (brass) should not be used in HF services. Due to its susceptibility to high corrosion rates, HSC-HF, and mechanical damage due to its softness, copper should not be used for permanent installations in HF services.

6.2.3.4 Aluminum

Aluminum is readily attacked by HF. Aluminum is also a very soft and easily damaged metal, making it especially susceptible to cross-threading when installing screwed fittings, which can lead to leaks. As such, aluminum and aluminum alloys shall not be used in HF services, including in sample containers.

6.2.3.5 Castings

Due to the varied manufacturing techniques used for making castings, stringent inspection and QC parameters should be specified. Castings covered by this include components of valves (including control valves), instrumentation, pumps, etc. The inspection guidelines in API 610, Class 3 for pumps and ASME B16.34 or API 20A for valves should be followed. The amount of inspection to determine pressure boundary integrity for cast components, especially casting defects, should be specified by the purchaser. There have been cases of undetected sand hole or shrinkage defects causing through-wall leaks on cast components after being put into HF service, even after stringent inspection and testing. For this reason, cast equipment is included in the acid detecting paint program—see 6.5.13. Purchasers of cast valves should satisfy themselves that the testing requirements in API 598 are met, as this is often not required and does not always happen for standard valve bodies built to standard requirements. See G.2.8 for further information.

As niobium carbides are preferentially corroded by HF, Alloy 400 castings should be made of ASTM A494 Grade M35-1. Grades M25S, M30C, M30H, and M35-2 should be avoided. Note that silicon additions in M35-1 castings have not been reported to impact the corrosion resistance of this alloy in HF service.

The heat-treatment requirements and recommendations of this section should be applied to major repairs on new castings and all repairs on existing castings (reference 6.3.2.4). Some owner-operators require heat treatment of all casting repairs.

The inspection and QC parameters beyond what are normally required for cast valves should include but are not limited to the types of testing from Table 2. Similar requirements should be considered for casting repairs.

Table 2—Types of Testing Typically Recommended for Cast Valves

Type of Testing Typically Recommended	How Owner-Operators Have Specified These Tests to Be Performed
Magnetic particle or liquid penetrant	ASME/ANSI B16.34, Appendix II or III
Helium leak test	ASME/BPVC Section V, Article 10, Appendix I, Bubble Test—Direct Pressure Appendix II, Bubble Test—Vacuum Box Technique Appendix IV, Helium Mass Spectrometer Tests—Detector Probe Technique Appendix V, Helium Mass Spectrometer Tests—Tracer Probe Technique Appendix IX, Helium Mass Spectrometer Test—Hood Technique
Radiographic ASME/ANSI	ASME/ANSI B16.34, Appendix I
NOTE For pumps, inspection beyond what is normally required is typically performed to API 610, Class 3.	

6.2.4 Nonmetallic Materials

6.2.4.1 Silicon

HF readily attacks materials that contain silica, and the reaction products can be significantly more corrosive to unit metallurgies than HF. Because of this, asbestos, glass, refractories, silica-containing catalyst support, silicone, and other silica-based materials shall not be used in HF services. Further, these materials should not be used in normally non-HF services that could be exposed to HF if an upset were to occur. For glass, these restrictions apply even when used in conjunction with a protective shield made of HF-resistant material [e.g. polychlorotrifluoroethylene (CTFE)-coated gauge glasses]. Materials used for turnarounds and maintenance that contain silica, such as blasting grit, should be thoroughly removed from HF alkylation unit equipment and piping before returning the equipment or piping to service. Some materials that can contain silicone include barrier fluids used in instrumentation, lubricants, polytetrafluoroethylene (PTFE) paste, ceramic packing, and valve packing materials. See G.2.10 for further information.

6.2.4.2 Plastics and Elastomers

While fully fluorinated plastics [e.g. PTFE, fluorinated ethylene propylene (FEP), and perfluoroalkoxy (PFA)] are HF resistant, they are also HF permeable. When used in HF service, they shall not contain any filler material that is known to be readily attacked by HF. Piping lined with these plastics is sometimes used between the bottom of the HF regeneration column and the downstream ASO treating drum. When designing plastic-lined pipe, flange joint integrity due to cold flow can be a challenge. Therefore, a retorquing plan for flanges in plastic-lined HF service piping shall be in place. When designing plastic-lined pipe, fire cases should be evaluated. Due to the potential for lining collapse, plastic-lined piping shall not be used where vacuum conditions could occur. See G.2.11 for further information.

6.2.4.3 Graphite

Graphite has been used extensively in HF-services, especially in gaskets. Graphite used in HF services shall not contain any material that is known to be readily attacked by HF. See G.2.10 for further information.

6.2.4.4 Anti-seize Agents

Anti-seize agents that contain silicone, magnesium, or lithium shall not be used in components that are or may be exposed to HF. These elements are readily attacked by HF. Anti-seize agents in HF services shall only contain materials that are not attacked by HF. Nickel-based and molybdenum di-sulfide with graphite flakes-based anti-seize agents have been used with success in HF services. See G.2.12 for further information.

6.2.5 Material Verification Program (MVP)

A written MVP in accordance with API 578 shall be in effect, including PMI, to verify that the nominal composition of an asset or asset component is consistent with the selected or specified construction materials. This includes all components, including instrumentation and valves, that may be exposed to HF. The HF alkylation unit PMI program requirements shall define the extent and type of PMI to be conducted during construction of new assets, retroactively on existing assets, and during maintenance, repair, or alteration. The HF alkylation unit MVP shall include PMI on all new and replacement carbon steel and alloys to be installed in HF services.

The focus on carbon steel PMI is based on the importance of identifying issues like the substitution of high-RE material for low-RE material or substitution of low-alloy steel material for carbon steel material to avoid localized acceleration of corrosion. PMI of carbon steel shall include elemental analysis (e.g. Cu, Ni, Cr). All weld metals shall be assumed to have a carbon content < 0.18 wt % for the RE calculation (Cu, Ni, Cr summation) if the carbon content is not measured. For other components, the carbon content should be assumed < 0.18 wt % for the RE calculation (Cu, Ni, Cr summation), if not verified.

All nonmetallic HF-resistant materials should be included in the MVP.

Field PMI of carbon steel can be used to avoid the use of inappropriate materials that may be similar in appearance to carbon steel, such as UNS K11789 (1.25Cr-0.5Mo steel) or UNS S41000 (410 SS). But most instruments are not capable of differentiating high-RE and low-RE carbon steel. The owner-operator shall review the instrument capabilities (e.g. the limits of detection) to ensure the instrument can detect the low-RE criteria. XRF, laser-induced breakdown spectroscopy (LIBS), and optical emission spectrometers (OESs) are technologies that have been used successfully by owner-operators. Additionally, the instruments shall be used per the manufacturer's requirements with careful attention to surface preparation as detailed in API 578 because small variations in technique and contamination can invalidate the results. Refer to G.2.2 and H.2 for further information.

Mill test reports (MTRs) shall not be substituted for PMI requirements, rather they can be used in conjunction with PMI. When composition information from the MTR and PMI testing reports is different for carbon steel RE content, some owner-operators have an independent metallurgical analysis performed.

Elements of the MVP should be in accordance with API 578 and should include, but not be limited to, the following.

- a) A process to identify, segregate, store, and deliver materials specifically for the HF alkylation unit.
- b) Applying all elements of the MVP to all areas where alkylation unit materials are received, stored, and delivered such as "satellite" or local equipment, components, and instrument storage areas.
- c) Including the acceptable examination methods, including the use of PMI testing methods such as portable XRF, LIBS, or OES, so that the precision of the test equipment is consistent with the established test objectives.
- d) Defining field requirements for materials verification.
- e) Defining the extent of PMI:
 - 1) typically, 100 % of pressure boundary components,
 - 2) typically, 100 % of individual components such as thermowells, valves, and instrumentation,
 - 3) valves, pumps, instruments, and other components that consist of multiple parts are not normally disassembled for material verification purposes; however, the owner-operator should require suppliers to certify that all factory/shop-assembled components (each individual assembly) have been constructed with the materials as specified, including components that cannot be subject to PMI after assembly.
- f) Defining examination results acceptance criteria.
- g) Including timing of material verification during the work process, as applicable (i.e. warehouse receiving/issuing, point of installation, etc.).
- h) A process for managing material nonconformances.
- i) Qualification and training, including refresher-training requirements, for personnel performing PMI and/or segregating HF alkylation unit-specific materials.
- j) The method of documenting and positively identifying materials that are verified, including transferring markings on unused portions of materials and parts (e.g. plates, pipes, bolts) before returning to storage.
- k) Calibration and verification practices for PMI testing equipment using certified standards prior to use and as specified by the equipment manufacturer.

- l) Material control methods for gaskets and bolting, including a means to indicate that they were verified.
- m) Verification of materials for gaskets and bolting at the point of installation, including a means to distinguish B7 and B7M studs and 2H and 2HM nuts.
- n) A process to remove questionable and unlabeled materials from designated storage areas.
- o) A process to clearly mark and segregate materials that have been tested and accepted for HF service from other materials.
- p) A process for verifying that only materials dedicated for HF service are issued for HF service, especially after normal working hours.
- q) A process to prevent Cu-Ni and Ni-Cu alloy bolts from being issued for pressure boundary closures.
- r) A process to verify unused materials returned to the storehouse or other designated alkylation unit-specific storage area before the material is returned to stock.
- s) A process to prevent materials that have not been verified from being installed in HF service.
- t) If PMI is performed by the supplier, a process to periodically audit the supplier's MVP program(s) and periodically conduct PMI on a random basis to validate supplier materials.

6.3 Specifications, Fabrication, and Repair

6.3.1 Pressure Vessel and Piping Specifications

Each new or replacement pressure vessel in HF service shall have complete written specifications that cover issues specific to HF service. These specifications shall be consistent with this document. Each operating HF alkylation unit shall have complete written specifications for piping in HF service. These specifications shall, as a minimum, cover construction materials, minimum pipe sizes, minimum wall thicknesses, corrosion allowances, welding hardness limits, PWHT requirements, flange ratings, bolting, gasketing, valves, and packing. Specifications for piping shall be maintained consistent with the requirements in this recommended practice.

The owner-operator shall have a documented process to manage the risk associated with deviations from specifications and standards for equipment and piping in HF service.

6.3.2 Fabrication and Repair

6.3.2.1 Carbon Steel Base Metal Specification

The following outlines carbon steel base metal specifications for piping and equipment in HF service.

- a) Carbon steel should be fully killed, except for air cooler and heat exchanger tubing.
- b) Carbon steel plate should be supplied in normalized, normalized and tempered, or quench-and-tempered heat-treated condition.
- c) Heat treatment of forgings shall be governed by the applicable ASME Code or ASTM Standard. Some owner-operators choose to normalize forgings.
- d) Carbon steel plate used in large diameter seamed piping and equipment should include specifying requirements for base metal cleanliness and PWHT per NACE 5A171 and NACE 8X194.
- e) Carbon steel base metal hardness shall not exceed 200 HBW per ANSI/NACE MR0103/ISO 17945.