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American Gas Association

# Management of Older LNG Facilities

## Beyond the Minimum & Challenges

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# Focus of Presentation

- To maintain the safe operation of LNG plant while it is AGING
- To identify a process in which equipment data can be considered in determining that an LNG facility and its components are operating safely and meeting performance and reliability expectations despite years of "aging" through operational and stand-by periods.
- This presentation is based on a paper and presentation provided at the AGA Operations Conference, Grapevine, TX. April 25, 2007 by Richard A. Hoffmann, P.E. of Hoffmann & Feige, and Kevin Ritz, BGE

# AGA Overview

- AGA
  - Founded in 1918, the American Gas Association (AGA) represents more than 200 local energy companies that deliver clean natural gas throughout the United States. Today, more than 68 million residential, commercial and industrial customers across the nation receive their reliable, affordable supplies of natural gas from AGA members—and natural gas meets almost a quarter of America's energy needs.

  - Related to the LNG Industry, the AGA's Operating Section includes a committee focused on supplemental gas activities. The Supplemental Gas Committee (SGC) is comprised of Engineers and leadership of LNG, LPG Air plants, process engineering firms, design, construction and support company engineers and process equipment manufacturers.

  - Members on the SGC represent a majority of the LNG facilities (peak shaving, satellite, and several of the terminals).

  - Several members of the SGC participate in the regulatory/standards making process by serving as Technical Committee members representing AGA on the NFPA 59A LNG Standard and NFPA 59 Utility LP-Gas Plant Code.

# BGE Overview

- BGE
  - Founded in 1816, Baltimore Gas and Electric Company (BGE) is the nation's oldest gas utility. BGE, a subsidiary of Exelon Corporation and is Maryland's largest gas and electric utility.
  - **BGE is celebrating our 200 year anniversary as the first gas utility in the U.S.** It began in 1816 when Rembrandt Peale lit the first gas lamp in Baltimore, and it continues two centuries later.
  - Quick Facts
    - Service Area: electric, 2,300 square miles; gas, 800 square miles
    - Customers: 1.25 million+ electric; 650,000+ natural gas
    - Employees: approx. 3,200
    - Natural Gas Pipeline Network: More than 7,100 miles
    - Distribution & Transmission Power Lines: More than 25,000 circuit miles distribution; almost 1,300 circuit miles transmission

# LNG Background and Industry Activities

- Background
  - The US LNG industry surged in 1965 when a series of plants were built in the U.S. The building continued through the 1970s. These plants were not only used for peak shaving, but also for base-load supplies for places that never had natural gas prior to this.
  - During the 1970’s a number of import facilities were built on the East Coast in anticipation of the need to import energy via LNG.
  - Peak Shavers were being supplemented by the build-up of base load import terminals, but now the peak shaving facilities are considering adding liquefaction facilities
  - The development of shale gas has presented opportunities and challenges for the LNG industry
  - This shale gas boom in U.S. natural production (2010-2015), enabled by hydraulic fracturing (“fracking”), has many of the import facilities being considered or already approved for conversion to export facilities. The first U.S. LNG export was completed in early 2016.
  - LNG is also being leveraged to support gas transmission and distribution activities to offset gas outages during planned maintenance, inspections, and MAOP testing where necessary

# LNG Background and Industry Activities

- Activities
  - The use and development of LNG facilities to supply LNG as an alternate transportation fuel has risen dramatically speared by environmental efforts to reduce greenhouse gas emissions as well as economic advantages in some cases
  - US LNG Plant Statistics - 2014 Data:
    - 123 Total LNG facilities
      - 63% peak shaving, 19% satellite, 12% base load (import/export terminals, etc..), 4% mobile/temporary, 2% other (vehicle fuel production, etc..
    - 80 Different owner/operators
    - 97 Intrastate facilities / 26 Interstate facilities
    - Avg. In-service Age - 1980
    - Oldest Plant – 1965
    - Newest Peaking Plant - 2007

# Regulatory Compliance

- All Jurisdictional LNG Facilities Must Comply with the Following:
  - 49 CFR Part 191 Reporting (annual, incident, and safety related conditions)
  - 49 CFR Part 199 Drug and Alcohol Testing
  - **49 CFR part 193** Liquefied Natural Gas Facilities: Federal Safety Standards, and;
    - American Gas Association, ‘‘Purging Principles and Practices” 3rd edition, June 2001
    - API Standard 620, ‘‘Design and Construction of Large, Welded, Low pressure Storage Tanks,’’ 11th edition, February 2008 (including addendum 1 (March 2009), addendum 2 (August 2010), and addendum 3 (March 2012)
    - ASCE/SEI 7–05, ‘‘Minimum Design Loads for Buildings and Other Structures’’ 2005 edition (including supplement No. 1 and Errata
    - ASME Boiler & Pressure Vessel Code, Section VIII, Division 1: ‘‘Rules for Construction of Pressure Vessels,’’ 2007 edition, July 1, 2007
    - GRI–96/0396.5, ‘‘Evaluation of Mitigation Methods for Accidental LNG Releases, Volume 5: Using FEM3A for LNG Accident Consequence Analyses,’’ April 1997, (GRI–96/0396.5),
    - GTI–04/0032 LNGFIRE3: ‘‘A Thermal Radiation Model for LNG Fires’’ March 2004
    - GTI–04/0049 ‘‘LNG Vapor Dispersion Prediction with the DEGADIS 2.1: Dense Gas Dispersion Model for Vapor Dispersion,’’ April 2004
    - NFPA 59A LNG Standard 2001 edition. The 2006 edition is applicable for the Seismic Design Criteria for LNG Tanks and NDE of API 620 LNG Storage Tanks Only
    - **AND……**

# Regulatory Compliance

- All Jurisdictional LNG Facilities Must Comply with the Following:
  - NFPA 59A LNG Standard (2001)
    - All Incorporated by Reference Standards in NFPA 59A (2001)
      - NFPA 10 Portable Fire Extinguishers (1998)
      - NFPA 11A Medium & high expansion foam (1999)
      - NFPA 12 Carbon dioxide extinguisher Systems (2000)
      - NFPA 12A Halon 1301 fire extinguisher Systems (1997)
      - NFPA 13 Installation of sprinkler systems (1999)
      - NFPA 14 Installation of standpipe, private hydrant, and hose systems (2000)
      - NFPA 15 Water spray fixed systems for fire Protection (1996)
      - NFPA 16 Installation of foam-water sprinkler, and foam water spray systems (1999)
      - NFPA 17 Dry chemical extinguishing Systems (1998)
      - NFPA 20 Installation of stationary pumps for fire protection (1999)
      - NFPA 22 Standard for Water Tanks for Private Fire Protection (1998)
      - NFPA 24 Installation of private fire service mains and their appurtenances (1995)
      - NFPA 30 Flammable & Combustible Liquids Code (2000)
      - NFAP 37 Installation and Use of Stationary Combustion Engines and Gas Turbines (1998)
      - NFPA 54 National Fuel Gas Code (1999)
      - NFPA 70 National Electrical Code (1999)
  - <u>And about 20 or more!</u>
  - <u>And the Point Here Is?</u>

# Accepted Facts

- The LNG facility was properly engineered, designed, and constructed in compliance with the applicable regulations
- The LNG facility has been properly operated
- All inspections have and are being performed
- Maintenance is primarily preventive with a minor level of corrective maintenance
- All personnel are properly trained

# Management of Aging Facilities

- Aging assets (process/equipment/components) if not managed properly can lead decreased reliability, efficiency (energy consumption), equipment/component obsolescence which can potentially affect safety
- Addressing Aging Requires:
    - Maintaining existing equipment operationally while performing all the mandatory prescriptive regulatory requirements and,
    - Evaluating the operation, and maintaining the facility beyond the regulatory requirements to;
        - Maintain focus on safety and reliability
        - Identify techniques to extend equipment life.
        - Plan for replacement of components, major machinery as it becomes obsolete, inefficient, unreliable, or increases risk
            - Managing the replacement of components, major machinery, etc.. preparing specifications referencing regulatory requirements in some cases more than 15 years outdated is challenging

# Techniques Utilized to Manage Older LNG Facilities

- Asset Management
- Maintenance Management
- Risk Management
- Risk Assessment
- Inspection and Data Review
- Prioritization
- Execution of the Plan

# Asset Management

- Asset Management - A system that monitors and maintains things of value to an entity or group. It may apply to both tangible assets such as property, plant, buildings, and equipment and to intangible assets such as human capital, intellectual property.  Asset management is a systematic process of deploying, operating, maintaining, upgrading, and disposing of assets cost-effectively.
- Affective asset management requires implementing plans, control activities (policies, procedures) and monitoring activities to aid in making the appropriate decisions concerning the assets performance
- Requires integrated and strategic focus, organizational commitment and support from top leadership, company personnel, and other stakeholders to affectively implement and make sustainable
- There are a number of consensus standards available that provide information on implementation of asset management systems, as an example:
    - British Standard ISO 55000 series which supersedes PAS55
    - API RP-1173 Pipeline Safety Management Systems (recent published) contains a number of elements which might also be applied to assist in management of LNG facilities

# Maintenance Management

- Principally there are (3) approaches to maintenance, preventative, predictive, and corrective
- Corrective - Reactive, unplanned & unscheduled.  Operating equipment fails to operate as required.
- Preventive - Proactive, planned, at a previously established recurring frequency.
- Predictive - Proactive, planned work based on monitoring and equipment operating parameters.
- Well balanced programs - 80% Preventive/Predictive,  20% Corrective
- Records are a vital key to not only in demonstrating regulatory compliance but also in providing data to assist in the prioritization process

# Risk and Risk Management (Safety and Operational)

- Risk - The combination of the probability of a hazard resulting in an adverse event, and the severity of the event
- Risk management is the identification, assessment, and prioritization of risks (the effect of uncertainty on objectives), followed by coordinated and economical application of resources to minimize, monitor, and control the probability and/or impact of an event to assure uncertainty does not impact the goal
- Regulations, codes and standards are aimed at minimizing risk to the physical facility, its personnel and the surrounding public based on requirements for design, materials, construction, testing, maintenance, and operation
- Other risk influences are perceptions of the public, government, and regulators of the industry to operate safely, typically speared by industry incidents (not just LNG related)
    - The consequences of this increases potential for additional regulation
- Risk is not constant, conditions change with time.
- Risk does not disappear, it can only be minimized to the extent that no unacceptable risk remains
- The goal of any plant operator/owner should be first focused on mitigation of safety risks to operating personnel and that of the facilities surrounding public
- The preparation and execution of an action plan to address current and potentially future risks is essential

# Risk Assessment

- Identify which facilities/components present the greatest risk (downtime, production deceases, inefficiency, failure)
  - Facility examples are storage, vaporization, transfer, liquefaction, fire & safety systems, etc.
  - Factors to consider which influence risk (not all inclusive):
    - What components, assemblies store the largest volumes of product
    - What systems/components transfer the highest flow rates and operating pressures
    - How frequently is the facility cycled (startups/shutdowns)
    - Longest lead time to replace
- Uses inspections appropriate to component to maximize identification of degradation
- Determine potential impact of a failure of a specific component on facility down time
- Risk assessment assess probability and consequences of all potential events that comprise a system failure
- The risk assessment results can then be used along with other factors in repair-or-replace decisions

# Inspection and Data Review

- Develop an inventory of all components and equipment used in the various facility processes based upon the initial risk ranking
- Identify How Components Age / Deteriorate / Fail
- Utilize appropriate inspection guidelines when available along with any NDE (nondestructive evaluation) methods to determine present condition
- Compare this inspection data against original design / fabrication / maintenance, and operating data
- Analyze thoroughly to determine remaining life / fitness for continued service

# Equipment and Component List (example)

- Liquefaction Facility Equipment and Components (example)
  - Piping – Buried, above grade ambient, hot (insulated and/or uninsulated), cyclic (hot/ambient) insulated and/or uninsulated), cryogenic
  - Pressure Vessels
  - Pretreatment
    - CO2 removal system - Heaters (direct and/or Indirect), Pressure Vessels - Insulated (internal; or external), Uninsulated
    - Water removal systems
  - Compression - Refrigeration - Expanders, turbo expander/compressors, centrifugal, reciprocating
  - Drivers - Electric motors, Turbines
  - Ambient Air heat exchanges (Coolers)
  - Cold Box – exchangers, separators, expansion joints, thermal distance pieces, insulation
  - Control System – Instrumentation, SCADA
  - Safety Systems - Relief valves
  - Electrical System - Motor control system, wiring, conduit, cable trays
  - Ancillary Equipment - Instrument air, water/glycol cooling (piping, pumps, heat exchangers)
- List could be greatly expanded in addition to including equipment manufacture, model numbers, serial numbers, ratings, etc..

# How Components Age / Deteriorate / Fail

- Develop a list of potential aging, deterioration, and failure factors
- Based on a compiled list of components, identify how those components might potentially age, deteriorate, and/or fail
- Assign a risk value for impact of an unexpected aging, deterioration, and/or failure, including downtime and associated costs
- Determine for those listed equipment/components and failure mode what tools, techniques, methods that might be used to evaluate that components condition

# How Components Age / Deteriorate / Fail

- Corrosion
  - Internal
  - External
- Fatigue
- Wears out
- Over-pressurization
- Obsolescence

# Contributors to Aging, Deterioration / Failure

- Time – Age, Operating Hours
- Physical Plant Location
  - Atmospheric Conditions
    - Rain/humidity, water accumulations
    - Contaminants in air with corrosive properties
    - Extreme temperatures
- Operating Conditions
  - Number of startup/shutdowns,
  - Removal and return to service cycles
  - Pressure and/or temperature Cycles
  - Overload
- Gas Composition
- Insufficient Maintenance

# The Inspections

- Using the list of equipment/components begin inspections of higher risk equipment/components looking for the affects of aging, deterioration
- Identify techniques, procedures, practices , and equipment to be utilize to aid in the evaluation
  - Engine/compressor analysis
  - Lube oil analysis
  - Ultrasonic leak detection
  - Vibration analysis
  - Thickness testing (UT)
  - NDE techniques
    - X-ray, Die penetrant, Mag particle, Ultrasonic
  - Thermal imaging
  - NACE SP -0198 Control of Corrosion Under Thermal Insulation
  - Etc.

# Reviewing Plant Data

- Prioritize review of plant records and data based on risk assessment to determine the following:
    - Has the equipment/component ever failed?
    - Review failures for origin and cause
    - Has efficiency of plant changed?
    - Is more energy required to vaporize, liquefy?
    - Is liquefaction product meeting design specification?
    - Has gas quality changed, is it affecting operation?
    - Has plant down time increased?
    - Has equipment MTBF (mean time between failures) decreased?
    - Does preventative maintenance regularly turn into considerable corrective maintenance?
    - Does Instrumentation maintain accuracy or do set points drifts between maintenance?
    - Is there a lack of preventive maintenance scheduled?
    - Is the correct preventive maintenance being performed?
    - Is the maintenance frequency appropriate?

# Prioritization

- There are a number of approaches which can be taken to aid in prioritization of equipment/component importance and impact, this is just an example:
  - Based on the inventory of all components and equipment used in the various facility processes based upon the initial risk ranking develop an appropriate list of questions about the equipment/components.
  - Some of these questions are asset based and others may more resemble those from a process hazard review

# Prioritization

- The following is a list of questions an operator/owner might ask of themselves while attempting to rank the importance and impact to the facility if the equipment is inoperable or fails.
    - Identify Plant Process/System (vaporization, liquefaction, transfer, Fire Protection, Ancillary (air, electrical, I&C, etc..))
    - Plant Equipment/Component ID and description
    - Manufacturer, Model/Serial #
    - Estimated equipment replacement cost
    - Year Installed
    - Hours of Operation - Annually
    - Are there PM's assigned to this equipment?
    - If the equipment required replacement, would it risk plant "Grandfathering" if applicable?
    - If replaced, will the equipment/plant efficiency be improved?
    - Do you maintain spare parts in inventory?
    - Is the equipment manufacture still in business?
    - Do you maintain accurate manufacturer contact information?

# Prioritization

- List of questions – continued:
  - Does the manufacture still support your spare parts needs?
  - Does the manufacture provide service/maintenance support?
  - Are after market parts available?
  - Can non-available parts be manufactured in house?
  - Are non-OEM service providers available?
  - Has this equipment caused unplanned downtime within last 5 years or ever?
  - Is equipment critical to safely operating the facility?
  - Are there known deficiencies with the existing equipment?
  - Is there redundancy in the equipment/system? Example- redundant boiloff compressor, air compressor, vaporizer, pump, etc..
  - List impact to facility if failure of equipment occurred (gas/liquid release, over pressurization, loss of plant controls, fire, inability to vaporize, liquefy, control boil off pressure, etc.)
    - If product was released, how much and over how much time?
    - Are there passive or active equipment/fire protection to mitigate if a failure were to occur?
  - If the equipment failed, could the failure lead to a risk to the public or personnel?
  - If the equipment failed, could the failure lead to a reportable PHMSA Incident?
  - If the equipment failed and a release occurred, could there be an environmental impact including reporting requirements?

# Prioritization

- Apply a ranking system (points for example) to each of the responses to the questions and calculate results
- Rationalize the results
- Develop short and long term mitigation plans that might include:
    - Enhancing maintenance activities to lower risk score
    - Perform major overhaul/maintenance if it reduces risk score and is cost effective
    - Prepare specifications for replacement and request pricing and delivery lead times
    - Develop short and long term plan for executing above including budgeting
- Execute the plan
- Re-evaluate periodically

- The AGA Supplemental Gas Committee is currently working on a project to update the AGA LNG Preventative Maintenance Guidelines publication from the early 1990's. The committee intends to include asset management principles outlined in the presentation.

# Engagement in the Standards Updating Process

- AGA participates in the standards updating process of several consensus standards (NFPA 54, NFPA 59, NFPA 59A, GPTC, etc..)
- The AGA's Supplemental Gas Committee (SGC) has established Standards Task Forces (STF) which review new editions of NFPA 59A and NFPA 59 as they are published by NFPA
  - Public Inputs (PI's) are developed by the STF and submitted to NFPA per their standards revision cycle
  - The STF also develops and provides Public Comments (PC's) when appropriate based on the actions taken by the NFPA Technical Committee during their First Draft meeting where the earlier Public Inputs were considered
  - The STF has submitted a significant volume of PI's and PC's over the last (4) revision cycles (approximately 12 years) intended to enhance the safety of the plants covered by the NFPA 59A & NFPA 59 Standards
  - A significant percentage of the STF PI's and/or PC's have been accepted by the NFPA Technical Committee members over the years
- NFPA Technical Committee's are comprised of a balanced number enforcement authorities, insurers, manufacturers, engineering firms, industry organizations, and users (typically owner/operators), etc.. This balanced committee membership helps to ensure that any one of these groups cannot influence the decisions of the Technical Committee during evaluation of submitted PI's and/or PC's
- The AGA's Supplemental Gas Committee have representatives on the NFPA 59A Technical Committee
- The STF members are proud of their contributions to advance the standards through the NFPA revision cycle process over the past 12 years, however, this body of work to advance the standards to improve the safety of the facilities may be meaningless if the later editions of the NFPA 59A and NFPA 59 standards are not Incorporated By Reference in whole or in part in the regulations

# Challenges Managing Under Outdated Regulations and Consensus Standards

- Incorporated By Reference (IBR) in 49 CFR Part 193
  - NFPA 59A (2001) All Except Seismic, NFPA 59A (2006) Seismic Only
- Standards Not IBR
  - NFPA 59A (2006)
  - NFPA 59A (2009)
  - NFPA (2013)
  - NFPA 59A 2016
  - And all the Standards Incorporated by Reference in these later editions of NFPA 59A

# Challenges Managing Under Outdated Regulations and Consensus Standards

- The enforceable edition of NFPA 59A (2001) incorporates by reference other standards which themselves have been updated several times incorporating lessons learned, new techniques, technologies providing for enhanced safety and reliability of the plants applicable to the standard
- In some cases the enforceable edition of NFPA 59A (2001) incorporates by reference other standards which themselves are now no longer active and are addressed by newer standards.

# Challenges Managing Under Outdated Regulations and Consensus Standards

- Examples of conflicts and enhancements between enforceable editions and later editions are:
- Safety Factors for pressure vessels
- LNG Storage tank construction requirements have been restructured. API 620 doesn't cover it all any longer. It is now covered by new API 625, revised API 620 and revised ACI 376
- Later editions of NFPA standards for design, install, testing, and particularly maintenance of fire protection systems have been updated and reorganized
- Corrosion control enhancements

# Changes in Later Editions of NFPA 59A

- 2006 - Chapter 5 has was revised to cover double and full containment LNG storage containers. Definitions of these types of containers have also been added to the standard. Seismic design criteria for LNG containers have been revised to correlate with the requirements of ASCE 7, *Minimum Design Loads for Buildings and Other Structures*. Chapter 11 has was revised to add requirements for a contingency plan for potential LNG marine transfer incidents.

- 2009 - Additional vapor dispersion models have been allowed where they are evaluated and approved by an independent body using the new Model Evaluation Protocol developed by the NFPA Research Foundation. The Design Spill table has been revised to separate the design spill requirements for over-the-top fill/withdrawal containers, other containers, and process areas. Scope statements have been added to each chapter

- 2013 - Incorporates several revisions to promote consistency between NFPA 59A and the Code of Federal Regulations, as well as some new terminology and standards for design, construction of LNG storage tanks (API 625, a new API 620, and ACI 376) systems. Requirements for portable LNG facilities were enhanced and clarified in Chapter 5.9. In addition, Chapters 7 and 14 were reorganized for easier use.

- 2016 - A new definition for *LNG facility* has been added, and the definitions for *LNG plant* and *component* have been revised to maintain consistency with Part 193. Additional changes were made to improve the fire safe design of outer concrete containers to avoid explosive spalling during a fire event. Revisions have been made to requirements for inspections after repairs, detection of leaks, and post seismic events to provide greater confidence in the system's continued safety and integrity. The 2016 edition also incorporates several revisions to enhance the use of Annex A. NFPA documents that were listed in Annex A as informational references in prior editions have been moved into Chapter 12 as enforceable code in order to address the design and installation requirements for fire protection systems. New and revised annex material has been added for numerous sections to provide additional information, guidance, and clarification, as well as to point users to reference materials for further guidance.

# Summary

- Properly maintained, an LNG plant can be expected to have an excellent extended operational life.
- Obsolescence must be monitored and an effective plant maintenance and replacement program can only be beneficial to life extension studies
- The aging issues will continue to demand attention and action
- The LNG Industry has an exemplary safety record
- This record is to the credit of an industry that is active in maintaining its standards and quality of operation and is a testimony to the people operating the facilities, the stake holders, and regulators
- Incorporation by reference of later, preferably latest additions of NFPA 59A for the LNG industry and NFPA 59 for Utility LP-Gas Plants will aid both operators and the enforcement agencies to ensure these facilities are designed, constructed, tested, maintained and operated under more evolved standards that have incorporated lessons learned and new technology last 10-16 years

# Any Questions?

Thank You!