Best Practices Workshop:

Nondestructive Testing Methods for Mechanical Integrity

November 9 – 10, 2004
The Pyle Center, Madison, WI

Disclosure

DISCLAIMER OF WARRANTIES AND LIMITATION OF LIABILITIES

Best Practices Workshop:
Nondestructive Testing Methods
for Mechanical Integrity
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Tuesday, November 9th

8:00 am Welcome and Workshop Goals
Doug Reindl, IRC

- Review NDT technologies – methods, limitations, practices
- Review PSM requirements for NDT
- Exchange information between NDT contractors and end-users
- Identify best practices for conducting non-destructive evaluation for mechanical integrity

8:15 am Overview of PSM Requirements for Mechanical Integrity
Doug Reindl, IRC

- Applicability
- Written procedures
- Components
  - Piping
  - Vessels
  - Insulation
- Training
- Inspection and Testing
  - Methods
  - Frequency
  - Documentation
  - Equipment deficiencies
- Quality Assurance
- Relationship to Process Safety Information

9:45 am Break

10:00 am Overview of Current MI Standards in Refrigeration and Kindred Industries
Daniel Dettmers, IRC

- API 510 and API 570
- ANSI/API RP 572-2001
- API RP 574
- API RP 575
- ANSI/API RP 576-2000
- ANSI/API RP 578-1999
- ANSI/ASME B31.3-2002
- ANSI/ASME B31.5-2001
- ASME Section V - Nondestructive Examination (2001 edition)
- ANSI K61.1-1999/CGA G-2.1-1999
- IIAR Bulletin 109 & 110
- NBBI 2001 National Board Inspection Code (ANSI/NB-23)

12:00 pm Lunch

1:00 pm MI Focus Area Workshop
IRC staff facilitates – all participate

Attendees split into break-out groups to prioritize areas of focus for insuring the on-going integrity of ammonia refrigeration systems. Each group will develop a consensus list of priority areas to be shared with other attendees.

2:15 pm MI Focus Area Workshop Reports
IRC staff facilitates – all participate

Attendees report on the results of their breakout groups.

2:45 pm Break

3:00 pm NDT Best Methods for Ammonia Refrigeration – Contractor's Perspective
Jim Kovarik, ConAm Inspections

- Selection of NDT Technologies
- Damage Mechanisms
- Equipment and methods
- Keys to achieving a successful MI program
- Why should you initiate an MI Program

4:00 pm Mechanical Integrity Demonstrations/Reception

- Digital Radiographic Profiler: *Lixi, Inc.*
- Infrared Camera: *Infrared Solutions*
- Ultrasonic Thickness Gauge: *Panametric*
- Magnetic Particle/Liquid Dye Inspection: *Magnaflux*

8:00 am Mechanical Integrity Field Experiences

- Godan Nambudiripad: General Mills
- Dan Webb/Mike Carrell: CF Industries
- Bent Wiencke: Nestlé
- Steve Thiery: General Mills

Invited end users will share successes, failures & insights from their MI programs. Time will be left at the end for others to speak on their experiences.

10:00 am Break

10:15 am Data Requirements for Best Practices (Breakout Groups)
IRC staff facilitates – all participate

Group 1 - Inspection Requirements

The focus of this breakout group is to develop priorities for mechanical integrity inspections.

- The group will create a matrix defining the probability of a component to fail and the significance of the failure
- The group will then discuss the frequency, method and reasonable cost required to maintain the integrity of the components targeted by the matrix.

Group 2 - Needs of a proper MI program

This group will consider the needs of a proper mechanical integrity program by answering the questions:

- What resources, information, data, guidance, technology, outside support, etc. are required to support effective MI programs in this industry?
- Is this currently available in another industry, standard or organization?
- If available, does it make sense to import it to our industry?

Group 3 – Designing for Mechanical Integrity

This group will consider principles associated with "designing for mechanical integrity" by discussing 3 primary questions:

- What can designers (and manufacturers) do to improve the mechanical integrity of industrial refrigeration systems?
- What can contractors (refrigeration and NDT) do to improve the mechanical integrity of industrial refrigeration systems?
- What can owners/operators do to improve the mechanical integrity of industrial refrigeration systems?

12:00 pm Lunch

1:00 pm Breakout Group Reports
IRC staff facilitates – all participate

Attendees report on the results of their breakout groups.

2:15 pm Workshop Conclusion/Next Steps

IRC staff summarizes results, lessons and lingering questions from the workshop. Group decides what further actions need to be taken by designated organizations, the IRC, the workshop participants and the industry.

2:30 pm Adjourn

Tab 1

Welcome and Workshop Goals

Doug Reindl, IRC

November 9 – 10, 2004
The Pyle Center, Madison, WI

Welcome to the University of Wisconsin

The Pyle Center

702 Langdon St

Madison, WI

Messages: (608) 262-1122

Faxes: (608) 262-8516

IRC

University of Wisconsin-Madison

University of Wisconsin

Ammonia Refrigeration Series

- *Introduction to Ammonia Refrigeration*
  - *March 2-4, 2005*
  - *October 13-15, 2005*
- *Ammonia Refrigeration System Safety*
  - *April 13-15, 2005*
- *Design of Ammonia Refrigeration Systems*
  - *September 12-15, 2005*
- *Ammonia Refrigeration Piping*
  - *November 2-4, 2005*
- *PHA in Ammonia Refrigeration (NEW)*
  - *September 28-30, 2005*
- *Intermediate Ammonia Refrigeration Systems*
  - *December 7-9, 2005*
- *Auditing Process Safety Management Systems*
  - *January 12-14, 2005*
- *Energy Efficiency Improvement Strategies*
  - *February 16-18, 2005*
- *Engineering Calculations for Process Safety and Risk Management*
  - *May 18-20, 2005*

Logistics & Other Information

- We will have refreshments and breaks throughout the day
- We will have lunch together
- Turn off cellular phones and pagers!
- Web terminals are available for your use

Our Goals

- Understand fundamental principles & practices for MI of piping systems to insure their continued safe operation
- Review NDT methods for piping systems & vessels
- Review current testing practices within & outside of the industrial refrigeration industry
- Identify gaps in current recommended mechanical integrity practices & identify measures to close those gaps

Ultimately, Our Goal is to

Make industrial refrigeration systems

SAFER!

Keys to Success

- Free exchange of ideas
- Respect information others provide
- Your involvement
- Your questions

MI Workshop

- Introductions
  - Name
  - Company
  - Experience with ammonia
  - This workshop will be a success for me if …

Tab 2

Overview of PSM Requirements for Mechanical Integrity

Doug Reindl, IRC

November 9 – 10, 2004
The Pyle Center, Madison, WI

<u>Learning Objective:</u> The objective of this segment of the program is to review the mechanical integrity provisions contained within the process safety management standard [29 CFR 1910.119(j)]. Additionally, background is provided to better understand the role of mechanical integrity in the context of achieving a safer more reliable system operation. OSHA provides more background information on each element of the standard in Appendix C.

At the end of this section, you should:

•Know the difference between “primary defense” and “secondary defense” for system safety

•Understand the importance of mechanical integrity for safe system operation

•Know the PSM requirements for mechanical integrity

Introduction

- Overview
- Review of Applicability
- 1910.119(j)
- OSHA – identified common problems with MI

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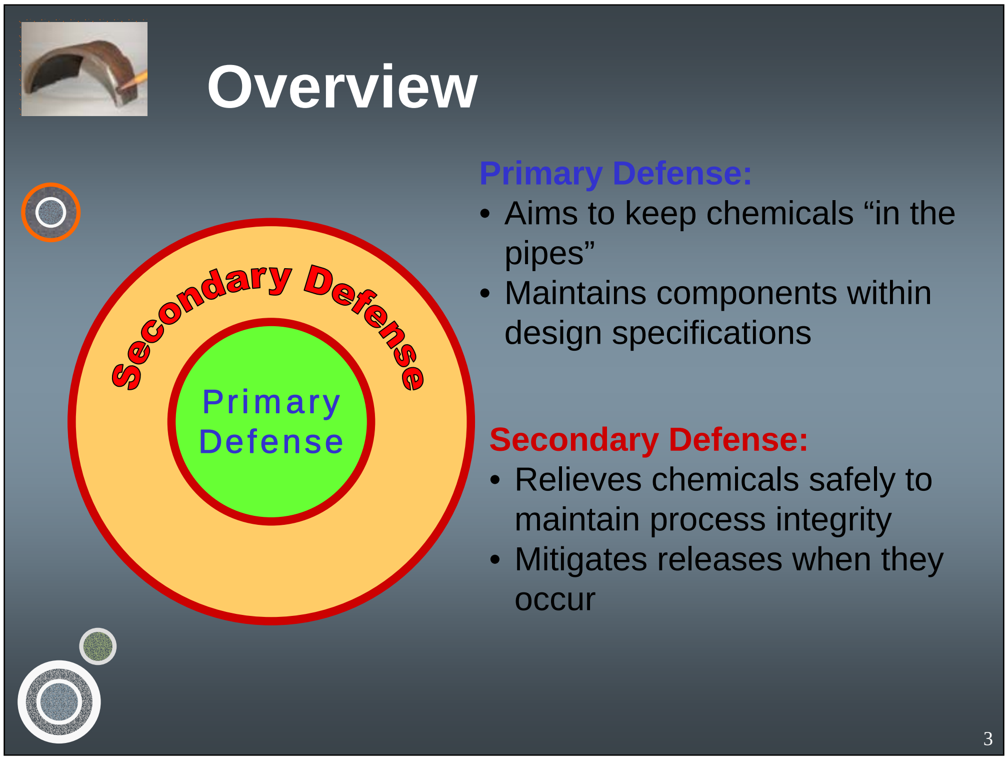
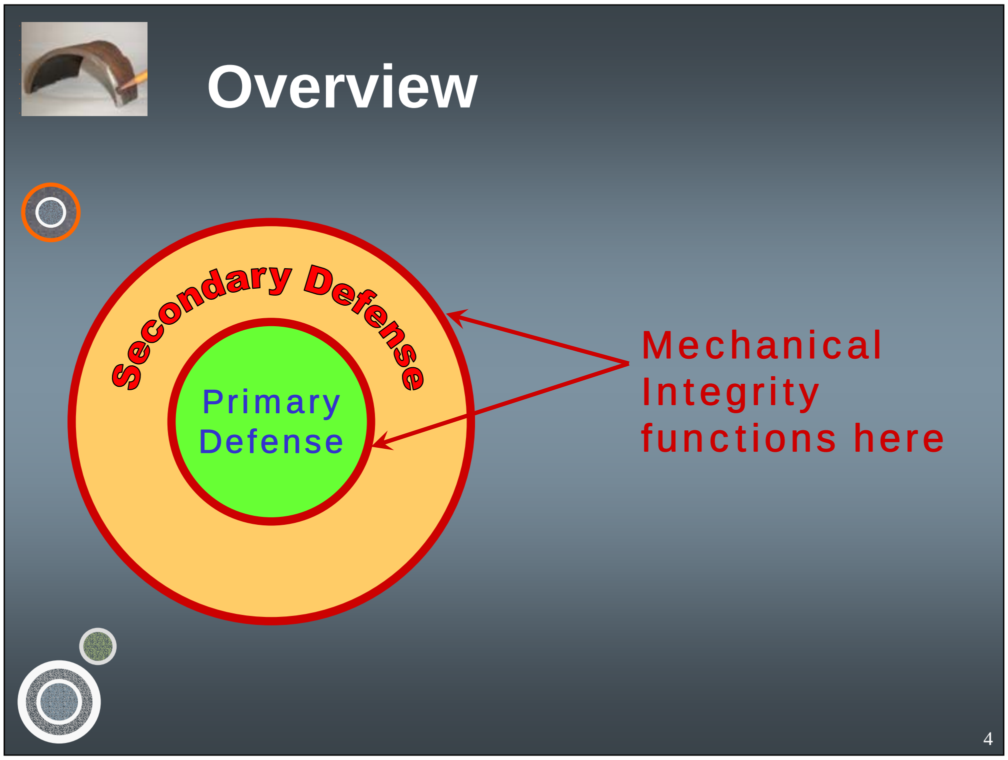


A preferred state of operation is to focus on "primary defense." That is, keeping the hazardous chemicals within the system. Effective mechanical integrity programs are able to achieve continued safe operation with reduced probability of accidental releases by applying appropriate inspections and tests to insure equipment is retired before failure. In cases where primary defense systems fail, the functional performance of secondary defense systems are essential. Secondary defense systems include: safety relief systems, automatic shutdown (king valve, zone solenoid valves, unclassified electrical equipment, etc.), ammonia detection system with associated alarms and controls, passive dikes, emergency ventilation, dump stations (fireman's dump, mixing stations, etc.), sprinkler systems, and other safety systems.



Mechanical integrity programs “wrap around” these primary and secondary safety systems to insure protection of personnel and other infrastructure. A goal of a mechanical integrity program is to make the primary and secondary defense systems “infallible.”

* Exception:

1919.119(a)(1)(ii)(A): Hydrocarbon fuels used for workplace consumption as a fuel (e.g., propane used for comfort heating, gasoline for vehicle refueling), if such fuels are not a part of a process containing another highly hazardous chemical covered by this standard;

1919.119(a)(1)(ii)(B): Flammable liquids stored in atmospheric tanks or transferred which are kept below their normal boiling point without benefit of chilling or refrigeration.

<u>Exceptions include:</u>

1919.119(a)(2)(i): Retail facilities;

1919.119(a)(2)(ii): Oil or gas well drilling or servicing operations; or

1919.119(a)(2)(iii): Normally unoccupied remote facilities

The above information is adapted from Appendix C of the PSM Standard.

The PSM Standard

(j) Mechanical integrity

(j)(1) Application

Paragraphs (j)(2) through (j)(6) of this section apply to the following process equipment:

(j)(1)(i) Pressure vessels and storage tanks;

(j)(1)(ii) Piping systems (including piping components such as valves);

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The PSM Standard (cont.)

- (j)(1)(iii) Relief & vent systems & devices;
- (j)(1)(iv) Emergency shutdown systems;
- (j)(1)(v) Controls (including monitoring devices and sensors, alarms, and interlocks) and,
- (j)(1)(vi) Pumps

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MI Scope

- Pressure vessels: high-pressure receivers, low pressure accumulators, intercoolers, thermosiphon pilot receivers, chillers, surge drums, transfer stations
- Refrigerant piping and valves
- Safety relief valves and vent systems
- Fire protection system components
- Emergency shutdown systems: limit cut-outs, electrical shutdown,

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MI Scope (cont.)

- Emergency ventilation
- Alarms and interlocks
- Ammonia detection systems
- Compressors
- Insulation systems : vapor retarder, insulation media, jackets
- Protective coatings: galvanizing, paint
- Supports: foundations, hangers, brackets, stands, anchor bolts, structural supports
- Heat exchangers: evaporators, condensers, desuperheaters
- Pumps: refrigerant pumps, water pumps

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The PSM Standard (cont.)

(j)(2) **Written procedures**

The employer shall establish <u>and</u> implement written procedures to maintain the on-going integrity of process equipment.

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Procedures

(j)(2) **Written procedures**

- No RTF maintenance programs
- Attempts to maintain process in as-designed conditions throughout its life
- Prioritize inspections based on risk accounting for MTBF, manufacturer's recommendations, historical performance
- Procedures should insure consistency of inspections – independent of personnel inspecting

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The PSM Standard (cont.)

(j)(3) **Training for process maintenance activities**

The employer shall train each employee involved in maintaining the on-going integrity of process equipment in an overview of that process and its hazards and in the procedures applicable to the employee's job tasks to assure that the employee can perform the job tasks in a safe manner.

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Training for MI Activities

- Training must insure maintenance personnel understand:
  - The overall mechanical integrity and maintenance program
  - Applicable safe work practices
  - Maintenance and inspection procedures
  - Proper use of test and measurement equipment required
  - Procedures for documenting the maintenance, inspection, testing, & results

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The PSM Standard (cont.)

- (j)(4) **Inspection and Testing**
  - (j)(4)(i) Inspections and tests shall be performed on process equipment
  - (j)(4)(ii) Inspection and testing procedures shall follow recognized and generally accepted good engineering practices

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The PSM Standard (cont.)

- (j)(4) **Inspection and Testing – cont.**

  (j)(4)(iii) The frequency of inspections & tests of process equipment shall be consistent with applicable manufacturers' recommendations and good engineering practices, and more frequently if determined to be necessary by prior operating experience

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The PSM Standard (cont.)

(j)(4) Inspection and Testing – cont.

(j)(4)(iv) The employer shall document each inspection and test that has been performed on process equipment. The documentation shall identify the date of the inspection or test, the name of the person who performed the inspection or test, the serial number or other identifier of the equipment on which the inspection or test was performed, a description of the inspection or test performed, and the results of the inspection or test.

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Inspection and Testing

- Industry practice – what is it?
- Applicable codes and standards?
- Manufacturer's recommendations
- Plant and company modifying experiences
- Personnel qualifications for conducting MI inspections/tests
- Utilize basic concepts like corrosion rates to modify your inspection intervals

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The PSM Standard (cont.)

(j)(5) Equipment Deficiencies

The employer shall correct deficiencies in equipment that are outside acceptable limits (defined by process safety information in paragraph (d) of this section) before further use or in a safe and timely manner when necessary means are taken to assure safe operation.

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Equipment Deficiencies

- Process Safety Information (d) is your repository for information to ascertain fitness for continued service
- Out of spec. equipment needs to be replaced
- Scheduling of repairs or replacement may require interim adjustments – reduction of pressure, modification of temperature or flow

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The PSM Standard (cont.)

(j)(6) Quality Assurance

(j)(6)(i) In the construction of new plants and equipment, the employer shall assure that equipment as it is fabricated is suitable for the process application for which they will be used.

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The PSM Standard (cont.)

(j)(6) **Quality Assurance - cont.**

(j)(6)(ii) Appropriate checks and inspections shall be performed to assure that equipment is installed properly and consistent with design specifications & the manufacturer's instructions.

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The PSM Standard (cont.)

(j)(6) **Quality Assurance - cont.**

(j)(6)(iii) The employer shall assure that maintenance materials, spare parts and equipment are suitable for the process application for which they will be used.

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Quality Assurance

- Closely related to management of change and pre-start-up safety review elements
- Verify quality and type of replacement components with approved system design

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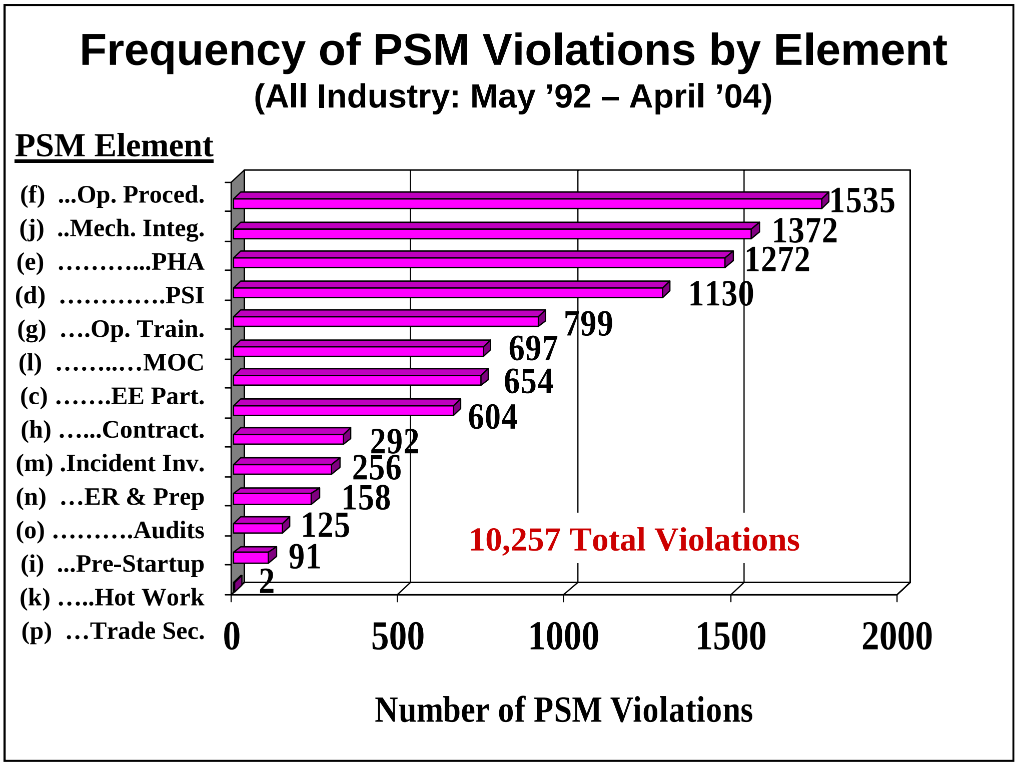
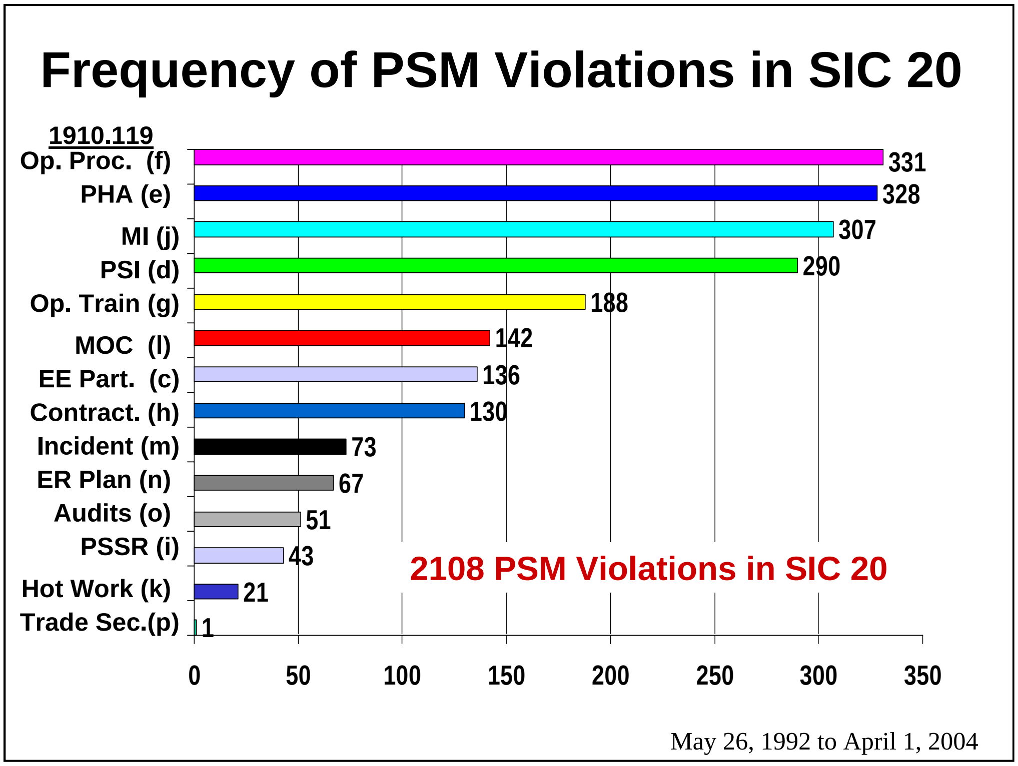

Frequency of PSM Violations by Element
(All Industry: May '92 – April '04)
PSM Element
(f) ...Op. Proced.
(j) ..Mech. Integ.
(e) ………...PHA
(d) …………PSI
(g) ….Op. Train.
(l) ……..…MOC
(c) …….EE Part.
(h) …...Contract.
(m) .Incident Inv.
(n) …ER & Prep
(o) ……….Audits
(i) ...Pre-Startup
(k) …..Hot Work
(p) …Trade Sec.
1535
1372
1272
1130
799
697
654
604
292
256
158
125
91
2
10,257 Total Violations
0
500
1000
1500
2000
Number of PSM Violations

Source: OSHA


Frequency of PSM Violations in SIC 20
1910.119
Op. Proc. (f)
PHA (e)
MI (j)
PSI (d)
Op. Train (g)
MOC (l)
EE Part. (c)
Contract. (h)
Incident (m)
ER Plan (n)
Audits (o)
PSSR (i)
Hot Work (k)
Trade Sec.(p)
331
328
307
290
188
142
136
130
73
67
51
43
21
1
0
50
100
150
200
250
300
350
2108 PSM Violations in SIC 20
May 26, 1992 to April 1, 2004

Source: OSHA

Most Cited SIC 20 PSM Standards

1910.119	Description
(f)(1)	Develop/implement written op.procedures
(d)(3)	PSI on equipment
(j)(2)	MI written procedures
(h)(2)	Contractor safety – Employer responsibilities
(e)(1)	Conduct PHA - identify/evaluate/control
(e)(3)	PHA 7 criteria which must be addressed
(j)(4)	Document each MI inspection/test
(g)(1)	Operator training - Initial
(l)(1)	Establish/implement MOC procedures
(c)(1)	Employee participation plan

Source: OSHA

OSHA Identified MI Problems

- No adequate testing to determine corrosion rate
- No comparison to, or definition of, good engineering practice
- No way to track material/components from purchase to final disposal
- No minimum acceptable wall thickness information for pipes or vessels
- Pitting Corrosion

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Conclusions

- Effective mechanical integrity programs
  - Keep your plant safer
  - Increase system reliability
  - Decrease un-scheduled downtime
  - Increase profitability
  - Necessarily, keep you OSHA and EPA compliant

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Tab 3

Overview of Current MI Standards in Refrigeration and Kindred Industries

Daniel Dettmers, IRC

November 9 – 10, 2004
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Overview of Current MI Standards in Refrigeration & Kindred Industries

Daniel Dettmers

Associate Researcher, IRC

IRC Mechanical Integrity Workshop

November 9-10, 2004

Refrigeration Industry "Standards"

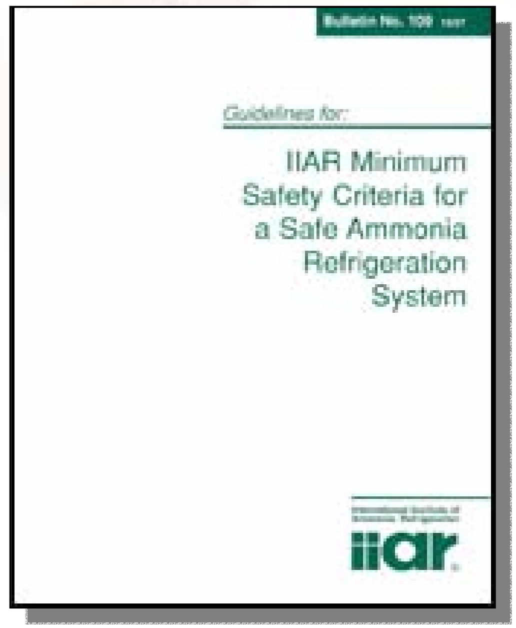
- **IIAR Bulletin 109-1997**: ***Guidelines for IIAR Minimum Safety Criteria for a Safety Ammonia Refrigeration System***
- **IIAR Bulletin 110-1993**: ***Guidelines for Start-up, Inspection and Maintenance of Ammonia Mechanical Refrigerating Systems***
- **ANSI/IIAR Standard 2-1999: Equipment, Design, and Installation of Ammonia Mechanical Refrigerating Systems**
- **ANSI/ASME B31.5-2001**: ***Refrigeration Piping and Heat Transfer Components***
- **ANSI/NBIC-23-2001: NBBI 2001 National Board Inspection Code**

Bulletin 109

Guidelines for:

IIAR Minimum Safety Criteria for a Safety Ammonia Refrigeration System
(1997)

- **The purpose of this bulletin is to present the *minimum* safety criteria and associated data sheets recommended for a safe ammonia refrigeration system for use by qualified individuals making safety inspections.**

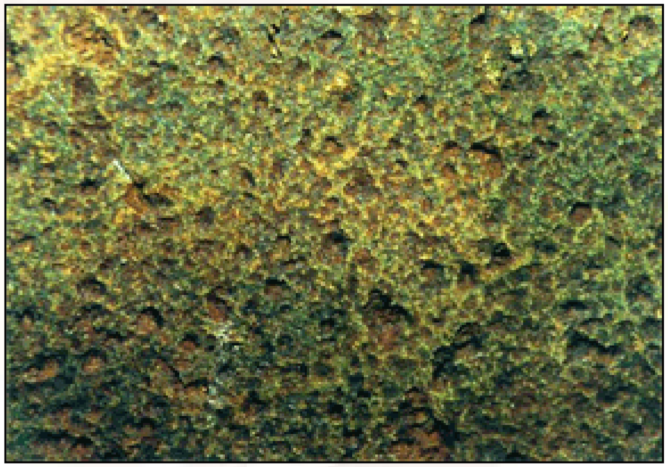

Guidelines for:
IIAR Minimum Safety Criteria for a Safe Ammonia Refrigeration System
iiar

Bulletin 109 – Pressure Vessels

4.3.4: If any heat exchanger or pressure vessel shows **signs of corrosion beyond mild surface corrosion**, the heat exchanger of pressure vessel should be further inspected for soundness by a professional engineer with expertise in the field, or an ASME inspector.

Bulletin 109 – Piping Systems

4.7.4: Uninsulated refrigerant piping should be examined for signs of corrosion. If corrosion exists, the pipe should be cleaned down to bare metal and painted with a rust preventative paint.

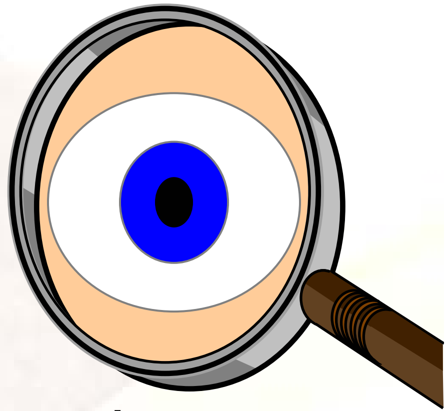


Badly corroded pipe should be replaced.

4.7.5: Insulated piping showing signs of vapor barrier failure should have the insulation removed and the pipe inspected. The pipe should then be treated in accordance with Section 4.7.3.

Bulletin 109 – Frequency

Frequency of Safety Inspections



- **5.1:** Each plant should have an owner's appointed representative responsible for compliance with all refrigeration safety requirements.
- **5.2:** Each owner should conduct ***annual*** **system safety check**.
- **5.3:** A more **thorough inspection** of an ammonia system safety should be conducted by a competent ammonia refrigeration engineer and/or fire safety official and/or other authority every ***five years***.

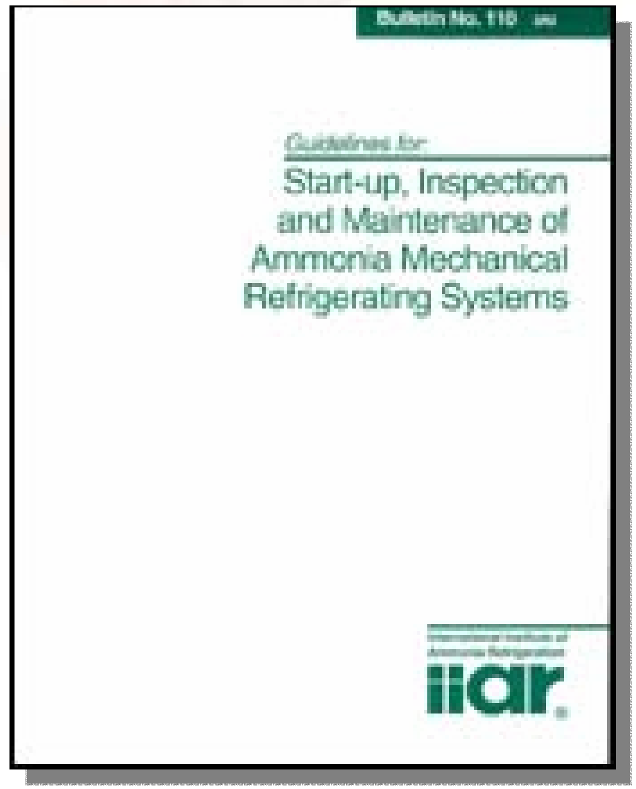
Bulletin 110

Guidelines for:

Start-up, Inspection and maintenance of Ammonia Mechanical Refrigerating Systems

(1993)

- **Provides basic requirements for safe start-up, inspection and maintenance of ammonia refrigerating systems.**
- **Specific requirements for a particular system must be considered when applying the general recommendations expressed in this document.**
- **All maintenance should be performed in accordance with equipment manufacturer's instruction manuals. Bulletin focuses on maintenance which promotes safety.**



Bulletin 110 – Pressure Vessel Inspection

3 levels of inspection specified:

- Routine Operational Maintenance
  - Part of regular O&M activities
- Annual Inspection
  - Yearly
- Independent Inspection
  - At least once every 5 years

Bulletin 110 – Pressure Vessels

6.4.2.1: Routine O&M

While system is operational, the external appearance of the surface of pressure vessels or S-T heat exchangers, or of the insulation applied to such pressure vessels or shell-and-tube heat exchangers, should be regularly checked by the system operating staff for deterioration.

Any deterioration should be recorded in system log, & repair(s) arranged.

Bulletin 110 – Pressure Vessels

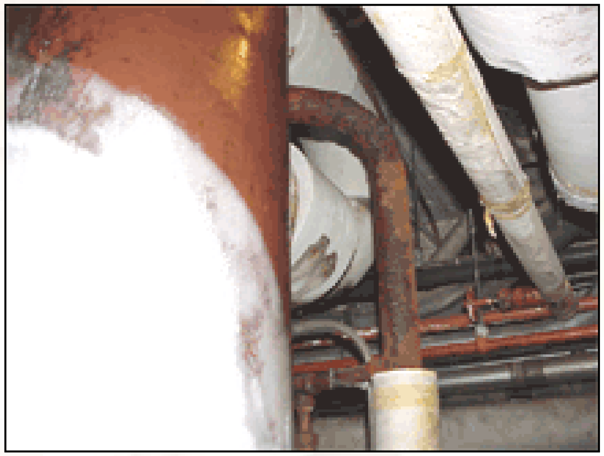
6.4.3 Annual Inspection

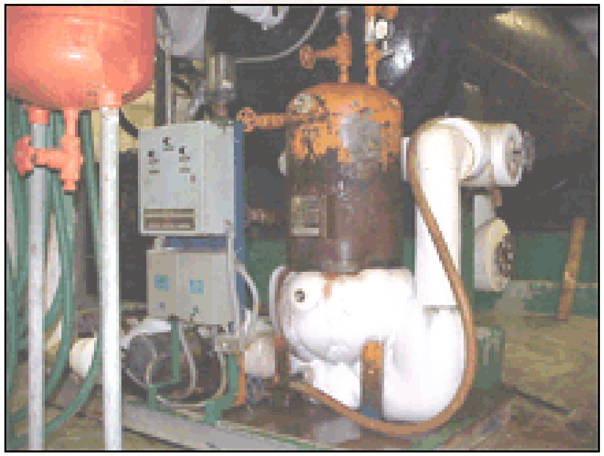
- The external surface or the insulation & associated vapor barrier should be inspected no less than **once every 12 months**.
- A system not in use for 3 months or more should be given an annual inspection before operating
- Purpose of inspection should be to discover whether the overall condition of the pressure vessels and heat exchangers, following a period of service under operational conditions, is sound and to ensure that **any deficiencies are thoroughly investigated and corrected**. The results of each inspection should be recorded and any corrective action noted.

Bulletin 110 – Pressure Vessels

6.4.3.1 Annual Inspection: Pressure Vessels

- Where visual inspection shows the vapor barrier on the thermal insulation to be intact, **no further inspection action is necessary**…
- Where a section of insulation is materially damaged, it **should be repaired or replaced**. Underlying area affected by surface corrosion should be cleaned, inspected, and appropriately treated before reinstatement of the protective finish, insulation, and vapor barrier.





Bulletin 110 – Pressure Vessels

6.4.4.1 Independent Inspection: General

- Pressure vessels and S-T heat exchangers should be given an independent inspection ***at least once every five years*** except where the authority having jurisdiction requires less frequency.
- The independent person should carry out such examinations and tests required to determine if the equipment is safe and recommend and necessary action
- **Pressure vessels and S-T heat exchangers of unknown origin should be replaced**. If a pressure vessel or shell-and-tube heat exchanger has been subjected to major repairs or alterations without proper documentation as required by the authority having jurisdiction, it should be replaced.

Bulletin 110 – Pressure Vessels

6.4.4.2 Independent Inspection: Uninsulated Pressure Vessels

- Uninsulated pressure vessels and S-T heat exchangers should be given a **thorough external visual examination**.
- Where surface corrosion exists that does not materially alter the thickness of the pressure-containing wall is found, the pressure vessel or S-T heat exchanger should be cleaned and repainted to limit further deterioration.

Bulletin 110 – Pressure Vessels

6.4.4.2 Independent Inspection: Uninsulated Pressure Vessels-cont.

- Where external corrosion has formed pits or caused material loss that reduces the thickness of the pressure vessel or S-T heat exchanger, ***the inspecting person should measure or cause to be measured the thickness of the remaining metal to determine whether the replacement is necessary***.
- …If the pressure vessel or S-T heat exchanger is accepted as suitable for further use, reports from all non-dest. testing should be filed in the maintenance records.

Bulletin 110 – Pressure Vessels

6.4.4.3 Independent Inspection: Insulated Pressure Vessels and S-T Heat Exchangers

– Special considerations arise in connection with insulated pressure vessels and S-T heat exchangers because inspection without removal of insulation is usually not practical and partial removal and replacement of insulation can often impair the vapor barrier and therefore resistance to corrosion.

– Where insulation is unsound or damaged, the insulation should be removed and the underlying pressure vessel or S-T heat exchanger inspected in accordance with Section 6.4.4.2.

Bulletin 110 – Piping

6.7.1 Uninsulated Piping

- All uninsulated piping and associated components such as flanges and supports ***shall*** be inspected ***annually*** for any damage to or deterioration of the piping or its protective finish; take remedial action where necessary. Areas affected by slight corrosion should be cleaned off and appropriately treated before reinstating the protective finish. Deeper pitting or loss of metal, where considered by subjective assessment to be **greater than 10% of original wall thickness, should be checked accurately by using techniques such as ultrasonic measurements**.

Bulletin 110 – Piping

6.7.2 Insulated Piping

- Any **mechanical damage** to insulation should be **repaired immediately & vapor seal reinstated** to prevent access of water vapor which will lead to breakdown of insulation & corrosion of pipework.

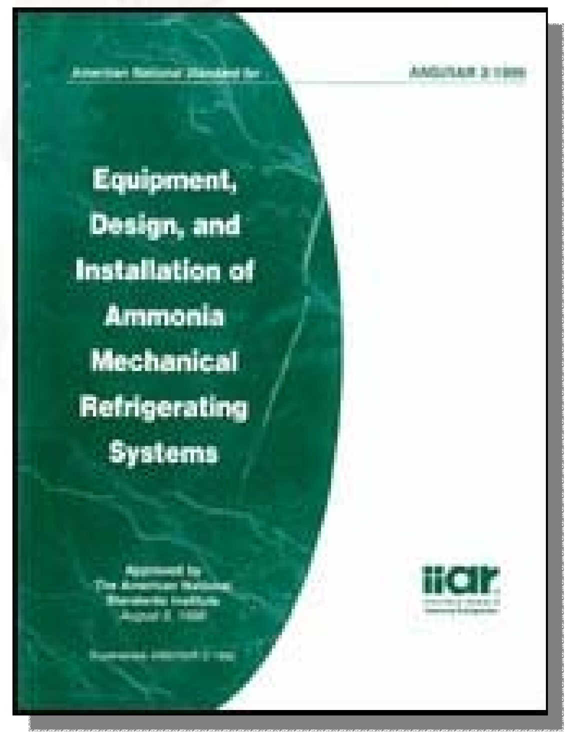
- At least as part of the annual piping inspection…**the external condition of the insulation and supports shall be inspected**…Sections of insulation which are obviously in poor condition shall be removed and the integrity of the exposed piping determined with the aid of non-destructive testing techniques, as appropriate. **Piping shall be replaced as necessary**, and protective coatings, insulation and vapor seal re-applied.

ANSI/IIAR Standard 2

ANSI/IIAR Standard 2-1999

Equipment, Design, and Installation of Ammonia Mechanical Refrigerating Systems

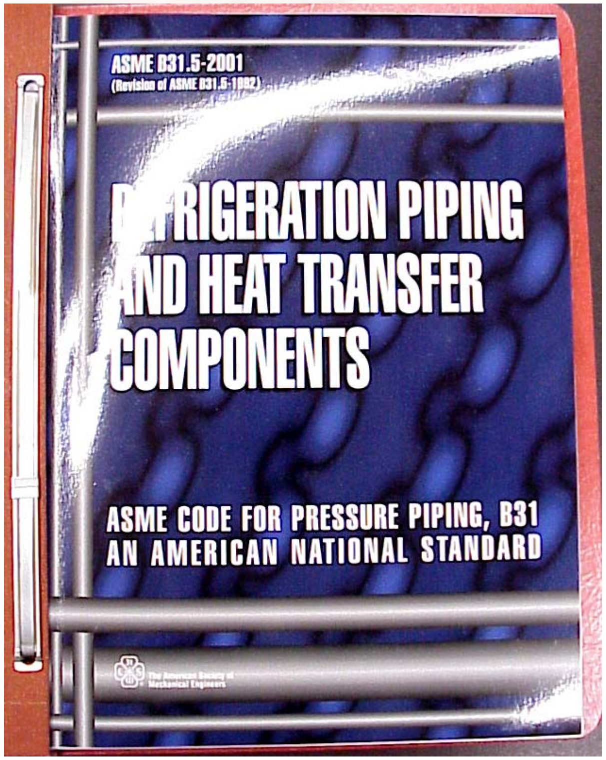
- **Intended to serve as a standard for the design, fabrication, manufacture, installation and use of ammonia mechanical equipment.**
- **Also specifies everything to be leak tight by pressure testing or other methods.**



ANSI/ASME B31.5-2001

ANSI/ASME B31.5-2001: *Refrigeration Piping and Heat Transfer Components*

- *Prescribes requirements for the material, design, fabrication, assembly, erection, test and inspection of refrigerant, heat transfer components, and secondary coolant piping.*
- *Specified by IIAR Std.2 for piping installation.*



ANSI/ASME B31.5-2001

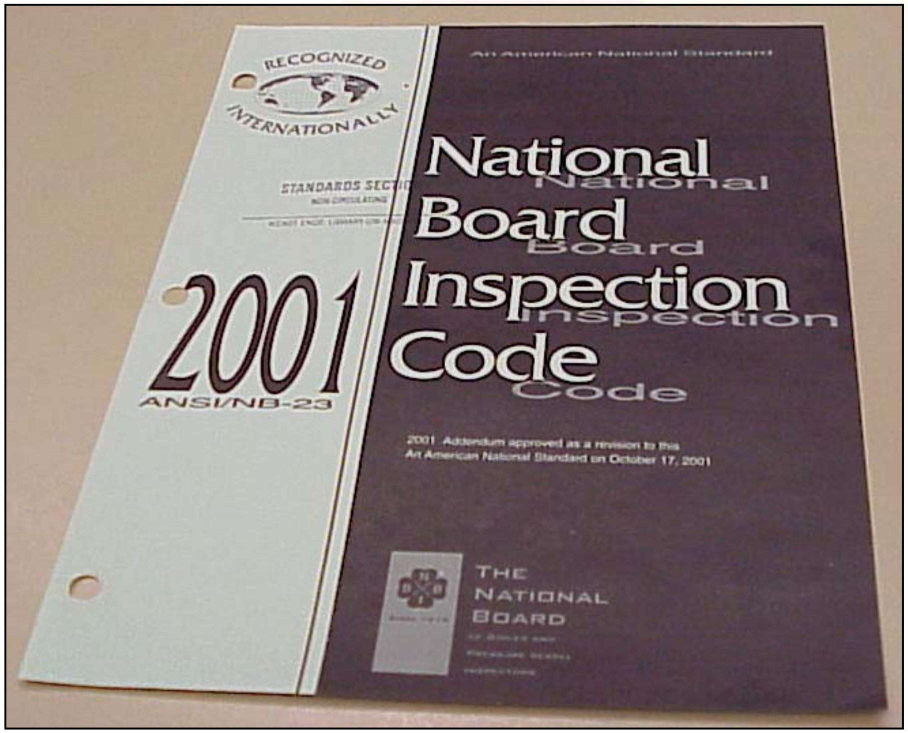
Chapter 6: *Examination, Inspection and Testing*

- Prescribes the requirements for the inspection of refrigerant piping prior to installation, after installation but prior to startup and necessary record keeping
- *536:Examination by the manufacturer, fabricator or erector*
  - *Requires visual examination of the piping system prior to operation*
  - Radiographic inspection of not less then 5% of all circumferential butt welds, miter groove welds and brazed joints for A3 and B3 refrigerants.
- 538:*Testing* specifies pressure levels for pressure and leak testing

ANSI/NBIC-23-2001

ANSI/NBIC-23-2001: NBBI 2001 National Board Inspection Code

- Developed to maintain the integrity of pressure retaining items after they have been placed into service by providing rules for inspection, repair and alteration, thereby ensuring that these objects may continue to be used safely.
- Provides guidance for the process of inspection, repair and alteration but does not provide details for all conditions found in pressure retaining items.



ANSI/NBIC-23-2001

Part RB: ***Inservice Inspection of Pressure Retaining Items***

- **RB-3231:External Inspection**
  - **Inspect for erosion, dents, distortion, cuts, gouges, bulges, blisters, corrosion or other deterioration.**
  - **If insulation and corrosion resistant linings in good condition, removal not necessary,but advisable to remove small portions**
- **RB-3232:Internal Inspection**
  - **General visual inspection for corrosion, erosion, deformation, cracking and laminations**
  - **Welds, nozzles, liquid level lines, and areas opposite inlet nozzles carefully inspected for corrosion**

ANSI/NBIC-23-2001

Part RB: ***Inservice Inspection of Pressure Retaining Items***

- **RB-3740: Inspection of Liquid Ammonia Vessels, Inspection of Parts and Appurtenances**
  - **Visual internal inspection looking for obvious cracks (advanced SCC)**
  - **"It is not intended that the vessel provide for access. It is understood that internal inspections will be made if the vessel has access to the internal surfaces."**

Kindred Industry Standards

ASME

- **ANSI/ASME B31.3-2002:** Process Piping
- **ANSI/ASME B31.5-2001:** Refrigeration Piping and Heat Transfer Components
- **ASME 2001 ASME Boiler & Pressure Vessel Code; Section V:** Nondestructive Examination
- **ASME 2001 ASME Boiler & Pressure Vessel Code; Section VIII:** Pressure Vessels

ASME BPV, Section V: Nondestructive Examination

ASME 2001 Boiler & Pressure Vessel Code; Section V: Nondestructive Examination

- This Section contains *requirements and methods for nondestructive examination* which are referenced and required by other code Sections.
- It also includes manufacturer's examination responsibilities, duties of authorized inspectors and requirements for qualification of personnel, inspection and examination.
- Examination methods are intended to detect surface and internal discontinuities in materials, welds, and fabricated parts and components. A glossary of related terms is included.

ASME BPV, Section VIII: Pressure Vessels

ASME 2001 ASME Boiler & Pressure Vessel Code; Section VIII: Pressure Vessels

- This Division of Section VIII provides requirements applicable to the design, fabrication, inspection, testing, and certification of pressure vessels operating at either internal or external pressures exceeding 15 psig.
- Such pressure vessels may be fired or unfired. Specific requirements apply to several classes of material used in pressure vessel construction, and also to fabrication methods such as welding, forging and brazing.
- It contains mandatory and nonmandatory appendices detailing supplementary design criteria, nondestructive examination and inspection acceptance standards. Rules pertaining to the use of the U, UM and UV Code symbol stamps are also included.

Kindred Industry Standards

API Standards & Recommended Practice

- **API 510:** Pressure Vessel Inspection Code: Maintenance Inspection, Rating Repair and Alteration
- **API 570:** Piping Inspection Code: Inspection, Repair, Alteration, and Rerating of In-Service Piping Systems
- **ANSI/API RP 572-2001:** Inspection of Pressure Vessels
- **RP 574:** Inspection Practices for Piping System Components
- **RP 575:** Inspection of Atmospheric & Low Pressure Storage Tanks
- **ANSI/API RP 576-2000:** Inspection of Pressure Relief Devices
- **ANSI/API RP 578-1999:** Material Verification Program for New and Existing Alloy Piping Systems
- **ANSI/API RP 579-2000:** Fitness-for-Service

Kindred Industry Standards

CGA (Compressed Gas Association)

- **ANSI K61.1-1999/CGA G-2.1-1999: *American National Standard Safety Requirements for the Storage and Handling of Anhydrous Ammonia***
- **This standard does not apply to refrigeration systems where ammonia is used solely as a refrigerant. (1.1.2.2)**
- **Entire container must be postweld heat treated and steels used shall not exceed a tensile strength of 70kpsi. (5.2.2)**

Vessel Inspection

- **The following 3 slides are a compilation of the vessel inspection requirements of:**
  - **IIAR 109 & 110**
  - **NBIC-23**
  - **API 510**

Comparison of Pressure Vessel Inspection Requirements in Refrigeration and Kindred Industry

Code	Type of Inspection	Component Description	Inspection	Remediation	Frequency
IIAR 109 (1997)		All pressure vessels	If signs of more then mild corrosion, should inspect further by professional engineer or ASME inspector (4.3.5)	None listed	- Annual ammonia safety check (5.2) - Thorough inspection every 5 years (5.3)
IIAR 110 (1993) including (2004 addenda)	Routine Operational Maintenance (6.4.2.1)	Uninsulated vessels	External surface appearance should be regularly checked for deterioration.	Deterioration that is found should be repaired.	Along with operator's routine activities.
		Insulated Vessel	Surface of insulation should be regularly checked for deterioration		
	Annual Inspection (6.4.3.1)	Uninsulated Vessel	External surface should be inspected.	- If vapor barrier intact, no further action (insulated). - Where insulation damaged, inspect/clean pipe and reapply insulation and vapor barrier (insulated). - If large material loss, deal in accordance with section 6.4.4: Independent Inspection	No less then every 12 months.
		Insulated Vessel	Insulation and vapor barrier should be inspected.		
	Independent Inspection (6.4.4)	Uninsulated Vessel	Through external visual examination.	- No indication of deterioration; no action. - Surface corrosion that doesn't alter thickness; clean and re-paint. - External corrosion reducing thickness; measure thickness to determine if replacement is necessary.	At least once every 5 years.
		Insulated Vessel	- If operates above 32°F but below dew point, strip wet insulation and inspect. - Inspect whenever insulation is stripped.	- Wet insulation removed and surface below inspected. Treat with rust preventative and re-insulate. - If insulation unsound or damaged, remove and inspect surface in accordance with 6.4.4.2.	

Comparison of Pressure Vessel Inspection Requirements in Refrigeration and Kindred Industry

Code	Type of Inspection	Component Description	Inspection	Remediation	Frequency
NBIC-23	External Inspection (RB-3231)	General Pressure Vessel, Insulated	If insulation and corrosion resistant linings in good condition, removal not necessary. Advisable to remove small portions.		The maximum period between internal inspections or a complete on-stream evaluation of pressure vessels shall not exceed one-half of the estimated remaining life of the vessel or ten years, whichever is less. When the remaining operating life is less than four years, the inspection interval may be the full remaining safe operating life up to a maximum of two years.
		General Pressure Vessel	Surface to be inspected for erosion, dents, distortion, cuts, gouges, bulges, blisters, corrosion or other deterioration. Welds are also to be inspected.		
	Internal Inspection (RB-3232)	General Pressure Vessel	General visual inspection for corrosion, erosion, deformation, cracking and laminations Welds, nozzles, liquid level lines, and areas opposite inlet nozzles carefully inspected for corrosion		
	Liquid Ammonia Vessels (RB-3700)	Internal Inspection (RB-3740)	-Visual internal inspection looking for obvious cracks (advanced SCC) -“It is not intended that the vessel provide for access. It is understood that internal inspections will be made if the vessel has access to the internal surfaces.”	-If cracks discovered, calculate depth of grinding may be carried out for crack removal. (Keep minimum wall thickness in mind.) -Where possible, remove crack by grinding. -Re-inspect by WFMT to ensure removal. Acoustic emission and fracture mechanics also acceptable. -Weld repair for deeper cracks.	

Comparison of Pressure Vessel Inspection Requirements in Refrigeration and Kindred Industry

Code	Type of Inspection	Component Description	Inspection	Remediation	Frequency
API 510	External Visual Inspection	All pressure vessels	External visual inspection to determine condition of vessel, exterior insulation, supports and signs of leakage.	If distortion or defect observed, further testing is warranted by other NDT method.	At least every 5 years or at same interval as internal or on-stream inspection, whichever is less.
	Corrosion Under Insulation Inspection	Insulated Vessels	CUI inspection considered for vessels that operate between 25°F and 250°F or intermittently. This may require insulation removal.	Repair or replace following the requirements of ASME codes, the code to which the vessel was built or other specific pressure vessel rating codes.	
	Vessel Insulation	Vessels with over 10 yrs remaining life that are protected from external corrosion	Insulation does not need to be removed for inspection, but insulation/outer jacket should be inspected.	Repair damaged insulation/outer jacket.	At least every 5 years.
	Internal Inspection	All vessels	Internal inspection of on-stream inspection. On-stream inspection is the use of NDE procedures external to vessel.	Repair or replace following the requirements of ASME codes, the code to which the vessel was built or other specific pressure vessel rating codes.	Not to exceed the less of ½ of estimated remaining life based on corrosion rate or 10 years.
	Corrosion Rate Determination	All Vessels	Measurements to be taken by NDT methods, measurements at suitable openings or gauging of uncorroded surfaces next to corroded surfaces. A representative number of measurements to be taken on all major components, sample of nozzles and other appropriate areas of concern.		A. Calculated from vessels in same service B. Estimated from experience or published data C. Measurements taken every 1000 operating hours until rate determined.

Piping Inspection

- **The following 2 slides are a compilation of the vessel inspection requirements of:**
  - **IIAR 109 & 110**
  - **NBIC-23**
  - **ASME B31.5**
  - **API 570**

Comparison of Piping Inspection Requirements in Refrigeration and Kindred Industry

Code	Component Description	Inspection	Remediation	Frequency
IIAR 109 (1997)	Uninsulated Pipe (4.7.4)	Examine for corrosion	Clean pipe down to bare metal and paint with rust preventative paint. "Badly corroded pipe should be replaced." (4.7.4)	- Annual ammonia safety check (5.2) - Thorough inspection every 5 years (5.3)
	Insulated Pipe (4.7.5)	If sign of vapor barrier failure, remove insulation and inspect pipe		
IIAR 110 (1993 including 2004 addenda)	Uninsulated Pipe (6.7.1)	External surface appearance should be regularly checked for deterioration.	- Slight corrosion; clean and reinstate protective finish. - Loss of metal >10%; if wall thinning is confirmed, seek expert advice.	At least annually.
	Insulated Pipe (6.7.2)	Surface of insulation should be regularly checked for deterioration	- Mechanical damage to insulation; fix immediately. - Insulation in poor condition to be removed and pipe beneath inspected. Replace, re-insulate as necessary.	
NBIC-23	Piping Systems	Ensure there is: - Provision for expansion - Provision for adequate support - No evidence of leakage - Proper alignment of connections - Proper rating for service conditions - No evidence of corrosion, erosion, cracking or other detrimental conditions	Any defects or deficiencies in the condition, operating and maintenance practices of the piping system equipment should be discussed with the owner or user…and recommendations made for correction.	None specified.

Comparison of Piping Inspection Requirements in Refrigeration and Kindred Industry

Code	Component Description	Inspection	Remediation	Frequency
B31.5	Visual Inspection (536.4.1)	Performed, as necessary, during the fabrication and erection of piping components to verify design and procedure specifications are met.	Shall be as stated in Chapter V of the B31.5; 527 for welded joints, 528 for brazed and soldered joints, and 535 for other mechanical joints and assembly of hanger.	At time of manufacture, construction and erection.
	Additional examination for A3 and B3 refrigerants	-Not less than 5% of circumferential butt and miter groove welds fully inspected by radiography. -Not less than 5% of brazed joints examined by in-process examination.	Samples to be selected to ensure the work of each welder/fitter making joints.	
API 570	Class 1 piping	-Thickness measurements at inspection points at frequency listed for piping class. Used to determine corrosion rate and remaining life. -External visual examination, including for corrosion under insulation (CUI). -Appropriate % of pipe inspected for CUI under 1. damaged insulation and 2. suspect insulation	Repair or replace following the principals of ASME B31.3 or the code to which the piping system was built and in complete accordance with API 570.	Thickness-5 yr. Ext. Visual-5 yr. 1. 75% 2. 50%
	Class 2 piping			Thickness-10 yr. Ext. Visual-5 yr. 1. 50% 2. 33%
	Class 3 piping			Thickness-10 yr. Ext. Visual-10 yr. 1. 25% 2. 10%

Corrosion Rate

- **Test designed to determine the rate at which a pipe or vessel is corroding**
  - **Preformed by measuring the wall thickness of the testpiece at documented intervals**
  - **NDT method: Ultrasonic thickness gauge**
- **Used to determine *Remaining Life* or *Fitness for Service***

<table>
<tr><th>Source</th><th>Corrosion Rate or Degree of Corrosion</th><th>Remaining Life or Fitness for Service</th><th>Application</th></tr>
<tr><td rowspan="2">API 570</td><td>Long term (between last and initial inspections): $\frac{t_{initial} - t_{last}}{time}$ [in/yr]</td><td rowspan="3">$Life = \frac{t_{actual} - t_{minimum}}{corrosion\ rate}$ [yrs]
(use corrosion rate resulting in shortest remaining life)</td><td rowspan="2">Piping</td></tr>
<tr><td>Short term (between last and previous inspections): $\frac{t_{previous} - t_{last}}{time}$ [in/yr]</td></tr>
<tr><td>NBIC-23</td><td rowspan="2">a) calculated from data collected by owner or user on vessels in same or similar service
b) owner or user's experience, or from published data
c) determinations made after 1000 hours of service</td><td>Vessels and Piping</td></tr>
<tr><td>API 510</td><td>See API RP 579 for fitness for service determinations</td><td>Vessels</td></tr>
<tr><td>API 653</td><td>t_1 = the lowest average thickness of a profile
t_2 = the least thickness, in inches, in an area of corrosion, exclusive of pits</td><td>Fit for service if:
a) $t_2 \geq t_{minimum}$
b) $t_2 \geq .6t_{minimum}$
(corrosion allowance required for service until next inspection should be added to $t_{minimum}$)</td><td>Tanks</td></tr>
<tr><td>ASME B31.3</td><td colspan="2" rowspan="2">Selection of material to resist deterioration in service is not within the scope of this Code.</td><td rowspan="2">Piping and Heat Transfer Components</td></tr>
<tr><td>ASME B31.5</td></tr>
<tr><td>IIAR 109</td><td colspan="2">If the heat exchanger or pressure vessel shows signs of corrosion beyond mild surface corrosion, it should be further inspected for soundness. If corrosion exists on piping, the pipe should be cleaned down to bare metal and painted with a rust preventable paint. (4.3.4) Badly corroded pipe should be replaced. (4.7.4)</td><td rowspan="2">Piping, Vessels, and Heat Transfer Components</td></tr>
<tr><td>IIAR 110</td><td colspan="2">Where external corrosion has formed pits or caused material loss that reduces the thickness of the pressure vessel or shell-and-tube heat exchanger, the inspecting person should measure or cause to be measured the thickness of the remaining metal to determine whether the replacement is necessary…the design records…the design codes…the calculated minimum wall thickness, and the NBIC rules or other appropriate guidance for evaluating corrosion should be considered.
Actual metal thickness should be determined using an appropriate non-destructive testing technique, example: ultrasonic measurements. (6.4.4.2)</td></tr>
</table>

t_{actual} = the actual minimum thickness, determined at the time of inspection
$t_{minimum}$ = the minimum required thickness for the limiting section or zone

[Note: this enclosure replaces Section 6.4 of Bulletin 110 (3/93, revised 3/02) in its entirety, and amends Section 7.0]

Revision to Bulletin 110

(Approved by IIAR Board of Directors February 29, 2004)

6.4 Pressure Vessels and Heat Exchangers

6.4.1 General

This subsection covers routine maintenance and inspection of pressure vessels and heat exchangers. For the purpose of description in this Section 6.4:

- "pressure vessels" include pressure vessels with or without internal coils
- "heat exchangers" include shell-and-tube heat exchangers, evaporative condensers and air-cooled finned heat exchangers, hereinafter collectively termed

The frequency and type of checking, monitoring and inspection will vary with the particular conditions affecting the specific application and refrigerating system concerned. For the purpose of description in this Section 6.4:

- "regularly checking" is observation as a function of the refrigerating system operator's routine activities
- "monitoring" is observation as a function of the operator's routine activities which includes recording the specifically observed condition, status or operating parameter in the daily log
- "inspection" is a task-specific observation leading to an evaluation and written record of the findings

It is recommended that particular attention be given to systems in the period immediately following major alterations, major service or breakdown work, change of refrigerant, or start-up following any prolonged period of non-operation.

The frequency and type of inspection of pressure vessels and heat exchangers will vary with the application and location of individual systems. More-frequent inspections may be appropriate for the following cases:

- re-commissioning of a refrigerating system
- significant alteration of refrigerating system components
- corrosive or adverse environmental conditions
- information derived from current service conditions on the system or on similar systems
- possible adverse effects of cyclic loading

Major repair or alterations to a pressure vessel or shell-and-tube heat exchanger are required to be undertaken in compliance with the National Board Inspection Code (NBIC) (see 7.27) and the resulting compliance documents should be filed in the maintenance records.

6.4.2 Routine Operational Maintenance

The system should be checked regularly for the presence of non-condensable gases which should be purged as necessary from the receiver(s) and/or condenser(s), preferably into a non-condensable gas remover or purger but alternatively into water. Where an automatic purger is fitted, its correct operation should be monitored. If there is a large accumulation of non-condensable gases the reason should be investigated and the cause should be corrected.

At regular intervals indicated by the rate of oil addition to the compressor(s), accumulated oil should be drained from oil collection points, preferably into a regenerator to remove refrigerant. The procedures outlined in *IIAR Poster No. P5: IIAR Recommended Oil Draining Guideline* should be followed (see 7.26).

Heat-transferring liquids (example: brine, water) should be checked at regular intervals for concentration, pH and contamination, and treated as necessary.

The presence of contamination due to water ingress should be checked at regular intervals where this risk can occur. The procedures outlined in IIAR Bulletin No. 108 for water content testing should be followed (see 7.22).

6.4.2.1 Pressure Vessels and Shell-and-Tube Heat Exchangers

While the system is operational, the external appearance of the surface of pressure vessels or shell-and-tube heat exchangers, or of the insulation applied to such pressure vessels or shell-and-tube heat exchangers, should be regularly checked by the system operating staff for deterioration. Any deterioration found should be recorded in the system log, and repair(s) should be arranged.

Liquid level gauges should be regularly checked for oil build-up and the oil drained as necessary.

6.4.2.2 Air-cooled Finned Heat Exchangers

Cooling coils and defrost water drains on air-cooled finned heat exchangers should be regularly checked for frost build-up and defrosted as necessary. Settings and operation of automatic defrost controls should be adjusted as necessary.

Air-cooled finned heat exchangers should be regularly checked for:

- buildup of dirt or other contamination on tubes, fins, drive components and fans
- fin damage
- coupling wear on direct-driven fans
- belt tension on belt-driven fans

Cleaning and/or adjustment and/or repair should be undertaken as necessary.

Lubricate fan motor and shaft bearings according to manufacturer's instructions. Correct direction of air flow and fan rotation should be verified after every disconnection from the power supply. All guards should be correctly installed.

6.4.2.3 Evaporative Condensers

Evaporative condensers should be regularly checked for:

- water operating level
- correct operation of pan strainer and bleed valve
- buildup of dirt or other contamination in the pan
- correct operation of water distribution system and drift eliminators
- buildup of dirt or other contamination on the drive components or fans
- coupling wear on direct-driven fans;
- belt tension on belt-driven fans.

Cleaning and/or adjustment and/or repair should be undertaken as necessary.

Lubricate pump motor and fan motor and shaft bearings according to manufacturer's instructions. Correct direction of air flow and fan rotation should be verified after every disconnection from the power supply. All guards should be correctly installed.

6.4.3 Annual Inspection

The external surface or the insulation and associated vapor barrier applied to the external surface of vessels and heat exchangers should be inspected no less than once every 12 months.

A system that has not been in use for three months or more should be given an annual inspection before bringing it into service.

The purpose of the inspection should be to discover whether the overall condition of the pressure vessels and heat exchangers, following a period of service under operational conditions, is sound and to ensure that any deficiencies are thoroughly investigated and corrected. The results of each inspection should be recorded and any corrective action noted.

6.4.3.1 Pressure Vessels and Shell-and-Tube Heat Exchangers

Where visual inspection shows the vapor barrier seal on the thermal insulation to be intact, no further inspection action is necessary and this should be recorded on the annual inspection record.

Where a section of insulation is materially damaged, it should be repaired or replaced. Underlying areas affected by surface corrosion should be cleaned off, inspected and appropriately treated before reinstatement of the protective finish, insulation and vapor barrier.

Where the annual inspection reveals that external corrosion has formed pits or caused material loss that reduces the thickness of the vessel or shell-and-tube heat exchanger, then that pressure vessel or shell-and-tube heat exchanger should be dealt with in accordance with Section 6.4.4: Independent Inspection.

When accessible, the process side of tube bundles in shell-and-tube heat exchangers should be inspected and cleaned if necessary. Exception: shell-and-tube thermosiphon compressor oil coolers and shell-and-tube heat exchangers on secondary refrigerant applications which are either sealed or where the secondary refrigerant quality has been monitored and maintained.

The inspection frequency for pressure vessels or shell-and-tube heat exchangers operated intermittently may require modification due to:

- external corrosion
- internal corrosion if opened to the atmosphere
- fouling of the water or process side of the heat exchange surfaces

6.4.3.2 Air-cooled Finned Heat Exchangers and Evaporative Condensers

The annual inspection of air-cooled finned heat exchangers and evaporative condensers is limited to the visibly accessible refrigerant-containing tubes and headers.

Heavy pitting or loss of metal should be recorded in the system log and arrangements made for non-destructive testing, using an appropriate testing technique, example: ultrasonic measurements.

6.4.4 Independent Inspection

6.4.4.1 General

Pressure vessels and shell-and-tube heat exchangers should be given an independent inspection at least once every five years except where the authority having jurisdiction requires less than the five-year interval. This inspection should be carried out by a person who has the training and knowledge for this task, for example:

- an employee of the owner, competent to perform inspections and who is independent of the daily operating responsibilities for that installation
- an independent organization or individual competent to perform inspections
- an inspector from the insurance company who is licensed to write pressure vessel insurance
- a licensed inspector from the jurisdiction where the pressure vessel or shell-and-tube heat exchanger is located

This independent person should carry out such examinations and tests required to determine if the equipment is safe and recommend any necessary action. Attention should be paid to possible deterioration of areas around supports and the attachments.

Inspections of shell-and-tube heat exchangers should include the process side of tubes and tube sheets, when they are accessible. Exceptions:

- shell-and-tube thermosiphon compressor oil coolers
- shell-and-tube heat exchangers on secondary refrigerant applications which are either sealed or where the secondary refrigerant quality has been monitored and maintained

Pressure vessels and shell-and-tube heat exchangers of unknown origin should be replaced. If a pressure vessel or shell-and-tube heat exchanger has been subjected to major repairs or alterations without proper documentation as required by the authority having jurisdiction, it should be replaced.

6.4.4.2 Uninsulated Pressure Vessels and Shell-and-Tube Heat Exchangers

Uninsulated pressure vessels and shell-and-tube heat exchangers should be given a thorough external visual examination.

Where there is no indication that the mechanical integrity of the pressure vessel or shell-and-tube heat exchanger has materially deteriorated since installation or the last independent full inspection and where the maximum allowable working pressure for the pressure vessel or shell-and-tube heat exchanger is clearly recorded together with evidence of an earlier strength pressure test (example: at time of manufacture), no further action is required.

Where surface corrosion that does not materially alter the thickness of the pressure-containing wall is found, the pressure vessel or shell-and-tube heat exchanger should be cleaned and repainted to limit further deterioration.

Where external corrosion has formed pits or caused material loss that reduces the thickness of the pressure vessel or shell-and-tube heat exchanger, the inspecting person should measure or cause to be measured the thickness of the remaining metal to determine whether the replacement is necessary. In arriving at such a decision, the design records associated with the pressure vessel or shell-and-tube heat exchanger, the design codes that were in effect at the time of manufacture, the calculated minimum wall thickness, and the NBIC rules or other appropriate guidance for evaluating corrosion should be considered.

Actual metal thickness should be determined using an appropriate non-destructive testing technique, example: ultrasonic measurements. If the pressure vessel or shell-and-tube heat exchanger is accepted as suitable for further use, reports from all non-destructive testing should be filed in the maintenance records.

6.4.4.3 Insulated Pressure Vessels and Shell-and-Tube Heat Exchangers

Special considerations arise in connection with insulated pressure vessels and shell-and-tube heat exchangers because inspection without removal of insulation is usually not practical and partial removal and replacement of insulation can often impair the vapor barrier and therefore resistance to corrosion.

Experience has shown that the surface of insulated pressure vessels and shell-and-tube heat exchangers with sound insulation and vapor barrier seal that operate continuously at temperatures below 32°F (0°C) show no degradation. For such a pressure vessel or shell-and-tube heat exchanger for which annual inspection records are available and where visual inspection shows the vapor barrier seal to be intact, no further inspection action is necessary and this should be recorded on the inspection record.

Particular attention should be given to insulation and vapor barrier integrity on insulated pressure vessels and shell-and-tube heat exchangers operating above 32°F (0°C) but below the dew point. All wet insulation should be removed and the affected surface of the pressure vessel or shell-and-tube heat exchanger examined. The pressure vessel surface should be appropriately treated with rust preventative coating before being re-insulated. No attempt should be made to apply a protective coating or re-insulate while the pressure vessel or shell-and-tube heat exchanger surface or adjacent sound insulation is wet or frosted.

At any major repair or renewal of the insulation, the opportunity should be taken to examine the pressure vessel or shell-and-tube heat exchanger surface for external corrosion.

Where insulation is unsound or damaged, the insulation should be removed and the underlying pressure vessel or shell-and-tube heat exchanger inspected in accordance with Section 6.4.4.2.

[To be added to Section 7.0]

7.26 IIAR Poster No. P5, "IIAR Recommended Oil Draining Guideline" (b).

7.27 National Board of Boiler and Pressure Vessel Inspectors, The National Board Inspection Code (i).

i. National Board of Boiler and Pressure Vessel Inspectors
1055 Crupper Avenue
Columbus, OH 43229

Tab 4

Results of MI Focus Area Workshop

November 9 – 10, 2004
The Pyle Center, Madison, WI

First Breakout Group Instructions:

1. Hand out to the group the "First Breakout Group Worksheet". Have those that did not fill out the pre-workshop worksheet fill this out as we go along.
2. Run through the Group Sheets in front of the group asking how many of those present inspect (or would inspect if worked at a plant) each individual component. As you hit "other" categories, fill in.

   Stop for discussion as warranted and record in the comment area. This is to prompt some discussion prior to the voting. Talk about those that get many votes and those that don't get any, but should.
   (15 minutes)

3. Let group vote by placing #'s in the "Vote" box. 5 is most important 1 is least important.
   (10 minutes)
   a. "Geo" group has only 5 votes (5, 4, 3, 2, & 1) per section
   b. "Chevy" group has 2 votes (two 5's, two 4's, etc.) per section
   c. "Cadillac" group has unlimited votes of every number

4. Tally the vote and discuss the top vote getters and maybe a few of the bottom vote getters, also. Work up the questions listed in the "Comments" box.
   (35 minutes)

Mechanical Integrity Workshop

First Breakout Group Worksheet

The sheets that follow reflect the poster that is hung in the front of the room. Feel free to take your own notes on these pages.

Similar to the pre-workshop sheets you filled out, answer these questions to specify your **current** practices for inspection and testing at your facility.

Plant personnel: fill this out for your plant
Corporate Personnel: fill this out per your corporate policy
Other: fill out to either reflect a plant you have worked with or what you would do if you were in charge at a plant

The Questions and shorthand answers are as follows:

Do you inspect? - Is this component in the scope of your current MI program?
Y= yes, N = no, N/A = not applicable

Vote – This space is held for everyone to step up and enter a vote of 1 (least important) to 5 (most important).

Tally – This space is held for the sum of the vote in each category.

Comments – Once voting is complete, this section will be used to record comments submitted by the group members.

Vote: 5 (most important) to 1 (least important)

Evaporative Condensers:

Component	Do you inspect?	Vote	Tally	Comments: How Often? Expected Failure? Method?
Tube heat exchanger bundle				
Tube header				
Fill media				
Water distribution system				
Isolation valves				
Desuperheater (if equipped)				
Auto purger				
Purger piping and valves				
Other: ________________				
Other: ________________				

Vessels:

High pressure rec. (external)				
High pressure rec. (internal)				
Intercooler(s)/CPR (external)				
Intercooler(s)/CPR (internal)				
Low press. vessel(s) (external)				
Low press. vessel(s) (internal)				
Thermosiphon pilot (external)				
Thermosiphon pilot (internal)				
Oil separators				
Chillers (shell external)				
Chillers (shell internal)				
Chillers (tubes)				
Welds on any/all vessels				
Oil pots				
Other: ________________				

Vote: 5 (most important) to 1 (least important)

Piping:

Component	Do you inspect?	Vote	Tally	Comments: How Often? Expected Failure? Method?
Uninsulated piping always **above** 32°F				
Insulated piping always **above** 32°F				
Uninsulated piping always **below** 32°F				
Insulated piping always **below** 32°F				
Uninsulated piping fluctuating **above and below** 32°F				
Insulated piping fluctuating **above and below** 32°F				
High pressure liquid lines				
Hot gas supply lines				
Ammonia condensate return lines				
Wet suction return lines				
Thermosiphon piping				
Welds on any piping				
Insulation system jacket				
Insulation system vapor retarder				
Insulation media				
Insulation system sealants				
Base pipe preparation (coatings, sealants, paints)				
Other: ________________				
Other: ________________				

Vote: 5 (most important) to 1 (least important)

Valves & other components:

Component	Do you inspect?	Vote	Tally	Comments: How Often? Expected Failure? Method?
King valve				
Critical isolation valves (manual)				
Critical isolation valves (automatic)				
Pressure relief valves (atmospheric)				
Pressure relief valves (internal to system)				
Hydrostatic relief valves				
Reseating relief regulators				
Filters/Strainers				
Pressure regulators				
Hand-expansion valves				
Check valves				
Solenoid valves				
Butterfly valves				
Thermal expansion valves				
Motor control valves				
Gate valves				
Other: ________________				
Other: ________________				

Vote: 5 (most important) to 1 (least important)

Evaporators:

Component	Do you inspect?	Vote	Tally	Comments: How Often? Expected Failure? Method?
Evaporator tubing				
Evaporator headers				
Evaporator fins				
Condensate drain pan				
Hot gas defrost line				
Water condensate drain line				
Evaporators always **above** 32°F				
Evaporators always **below** 32°F, except when defrosting				
Jacketed vessels (silos, tanks)				
Other: ________________				
Other: ________________				

Other components:

Evap. condenser water pump				
Ammonia recirc. pump(s)				
Recip compressors				
Screw compressors				
Emergency ventilation system				
Liquid transfer systems (gas powered) including dump trap and piping				
Liquid transfer systems (mechanically pumped) including dump trap, pump and piping				
Other: ________________				
Other: ________________				

Results of First Breakout

IRC Mechanical Integrity Workshop November 9-10, 2004

Cadillac Group Results

Top 25 listed in voting priority

King valve	35
Critical isolation valves (manual)	35
Isolation valves	33
Critical isolation valves (automatic)	32
High pressure rec. (external)	30
Emergency ventilation system	29
Pressure relief valves (atmospheric)	28
Ammonia detection system	28
Water treatment	27
Tube heat exchanger bundle	26
Pressure relief valves (internal to system)	26
Evaporators always above 32°F	26
Evaporators always below 32°F, except when defrosting	26
Screw compressors	26
Jacketed vessels (silos, tanks)	25
Safety cut-out switches	25
Water distribution system	24
Fans, fan blades, belts, shafts, bearings	24
High pressure liquid lines	24
Auto purger	23
Insulated piping fluctuating above and below 32°F	23
Continuous ventilation	22
Filters/Strainers	21
Liquid transfer systems (gas powered) including dump trap and piping	21
Insulated piping always above 32°F	20

Chevrolet Group Results

Top 25 listed in voting priority

Pressure relief valves (atmospheric)	31
Screw compressors	29
Intercooler(s)/CPR (external)	26
Critical isolation valves (manual)	26
Emergency ventilation system	26
All alarms and shutdowns	26
Critical isolation valves (automatic)	25
Recip compressors	25
High pressure rec. (external)	24
Tube heat exchanger bundle	23
Auto purger	23
Insulated piping fluctuating above and below 32°F	23
King valve	23
Evaporator headers	23
Uninsulated piping fluctuating above and below 32°F	22
Insulation system vapor retarder	22
Evaporator tubing	22
Isolation valves	20
Hot gas defrost line	20
Evaporators always below 32°F, except when defrosting	20
Water distribution system	19
Ammonia reciculating pump(s)	19
Evap. condenser water pump	18
Tube header	17
Pressure relief valves (internal to system)	17

Geo Group Results

Top 25 listed in voting priority

Water distribution system	18
High pressure rec. (external)	17
Tube heat exchanger bundle	16
Pressure relief valves (atmospheric)	15
Critical isolation valves (manual)	14
Low press. vessel(s) (external)	12
Auto purger	11
Evap. condenser water pump	11
Recip compressors	11
Screw compressors	11
Intercooler(s)/CPR (external)	10
Insulated piping fluctuating above and below 32°F	10
Evaporator tubing	10
Isolation valves	9
Oil separators	9
Base pipe preparation (coatings, sealants, paints)	9
Evaporator fins	9
Tube header	8
Pressure relief valves (internal to system)	8
Emergency ventilation system	8
Uninsulated piping fluctuating above and below 32°F	7
Evaporators always below 32°F, except when defrosting	7
Insulation system vapor retarder	6
High pressure liquid lines	5
Insulation system jacket	5

Tab 5

NDT Best Methods for Ammonia Refrigeration – Contractor's Perspective

Jim Kovarik,
ConAm Inspections

November 9 – 10, 2004
The Pyle Center, Madison, WI

CONAM Inspection & Engineering Services, Inc.

University of Wisconsin Best Practices Workshop – Nondestructive Testing Methods for Mechanical Integrity

Jim Kovarik

November 9, 2004

NDT Best Methods for Ammonia Refrigeration Systems

- NDT Methods
- Damage Mechanisms
- Equipment & Methods
- Keys to Achieving a successful MI Program

NDT Methods

Historically, various NDT methods have been employed to assess the condition of Ammonia piping systems. These have included:

- Ultrasonic Thickness Measurements
- Profile Radiography
- Real-time Radiography
- Acoustic Emission
- Visual Inspection

These methods continue to be utilized today, but with much improved technological advances.

NDT Methods

The preferred NDT method to ascertain the condition of an ammonia refrigeration system should:

- Minimize insulation removal
- Be effective at detecting damage or corrosion
- Be cost effective
- Be employed quickly to reduce interference with production
- Deliver reliable results

Selection of NDT Technologies for Ammonia Piping Exams

Correct selection and evaluation of NDT techniques is critical to a successful examination. Selection criteria should include:

- Examination objectives
- Program motivation
- Piping system configuration
- Inspection locations
- Discontinuity detection considerations
- Screening versus Scanning
- NDT Technology capabilities & limitations

Piping Inspection Motivation

Why do we inspect?

- Regulatory Requirements
- Safety Considerations
- Assure Mechanical Integrity of System
- Reduce/Avoid Unplanned Downtime
- Economic Factors, i.e., cost of downtime, emergency repairs, etc.
- Maximize Efficiency
- To aid maintenance or repair planning

Piping System Configurations

Common piping system configurations that affect examination program design:

- Insulation
- Size – Diameter and Wall Thickness
- Pipe Material
- Accessibility, Clearance and Orientation
- Number and Location of Fittings
- Drained or Full
- Temperature

Damage Mechanisms

The most prevalent damage mechanism associated with ammonia piping systems is Corrosion Under Insulation (CUI). CUI manifests itself due to migration of water between the insulation and the pipe surface. In an ammonia refrigeration system, the water usually freezes when the system is in operation. Ice poses little threat to the service life of the piping, however, the cyclic thaw and refreeze cycle can wreak havoc on the piping system. Depending on the amount of water trapped at the insulation-pipe interface, corrosion can occur anywhere around the circumference of the pipe.

Damage Mechanisms

Another damage mechanism associated with ammonia systems is Stress Corrosion Cracking (SCC). Carbon Steel is susceptible to SCC in anhydrous ammonia service where the water content is below 0.2%. Contamination with air or oxygen increases the tendency for cracking. Cracking normally occurs at non-PWHT welds and HAZs. PWHT eliminates the susceptibility of most common steels that have less than 70 ksi tensile strength. Prevention/mitigation factors include PWHT, weld hardness below 225 BHN, and preventing ingress of oxygen into the process stream.

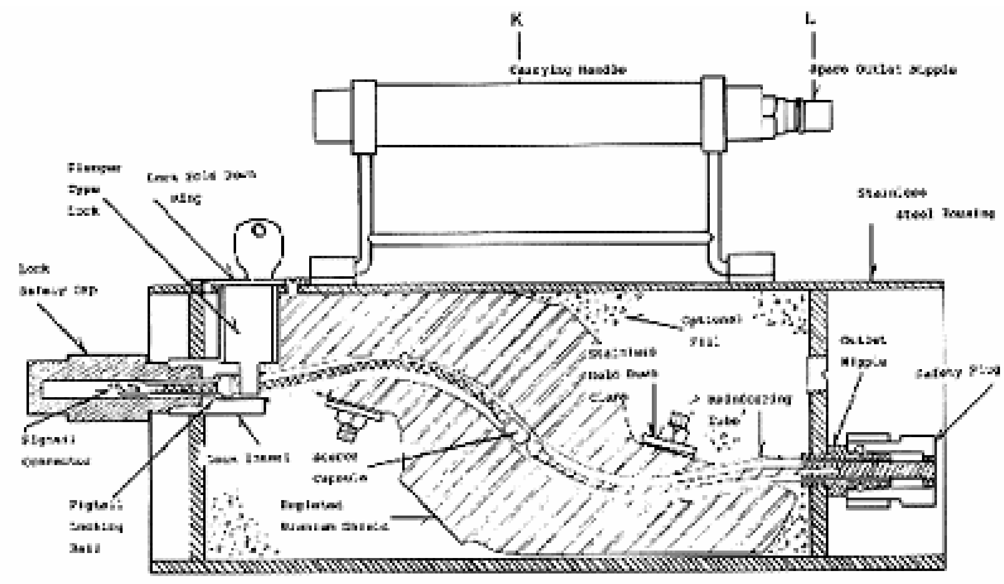
Equipment & Methods

Some of the more conventional NDT methods utilized on ammonia piping systems today include:

- Ultrasonic Thickness Testing (UTT)
- Radiographic Testing (RT)
- Magnetic Particle Testing (MT & WFMT)
- Ultrasonic Shearwave Testing (UT)
- Liquid Penetrant Testing (PT)
- Visual Testing (VT)

Digital Ultrasonic Thickness Meter

Used to establish thickness of materials from one side only by placing a transducer on the material being tested.



Ir_{192} Gamma Radiographic Camera

Used to image items of any material for the detection of internal defects or internal components.

Magnetic Particle Inspection Probes

Used to magnetize ferrous materials for the detection of surface and near-surface defects or discontinuities.

Magnetic Inspection Particles

Applied to the surface of the test piece during magnetization. The particles will align themselves along surface Discontinuities, enabling easier detection.

Video Probe Inspection

Used to visually inspect in areas which are not possible to view in any conventional manner. Most often used in tubing, intricate castings, or bundled components.

Equipment & Methods

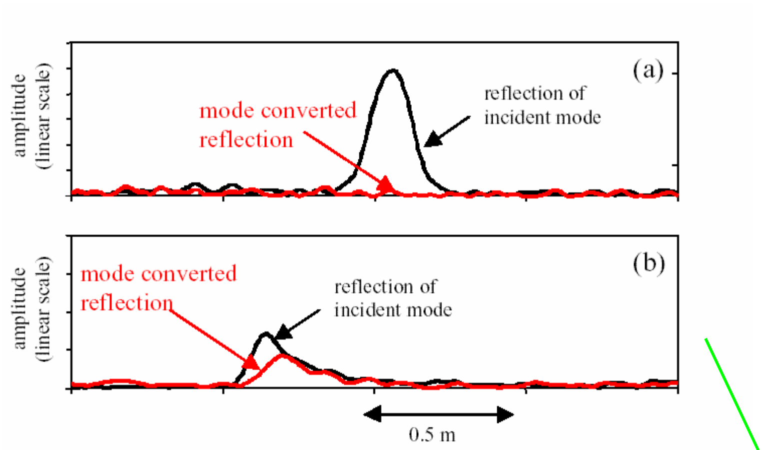
In addition to the NDT methods mentioned earlier, a few technologies now exist to perform less invasive inspections on ammonia piping systems. These include:

- GUL – Guided Ultrasonic Lamb wave
- Lixi Profiler
- Computed Radiography
- Acoustic Emission

GUL – Long Range UT

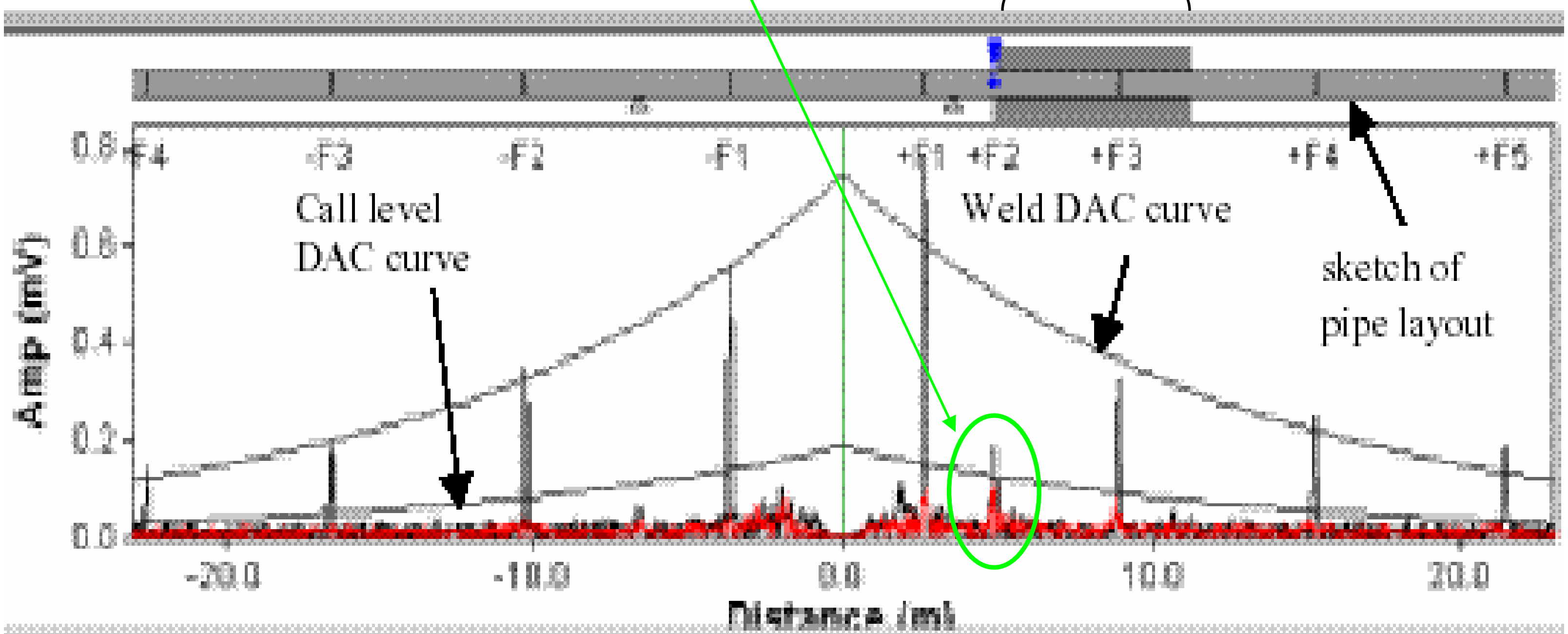
The GUL technique is capable of launching an Ultrasonic wave from a single point on a pipe to a distance of approximately 150’ in either direction (300’ total). Defects having a cross-sectional area of at least 10 to 15% may be detected with this method. It is designed to be a rapid, screening tool to identify areas on a piping system that require further investigation.

GUL Method of LRUT



Signal from axisymetric feature (i.e. – weld)

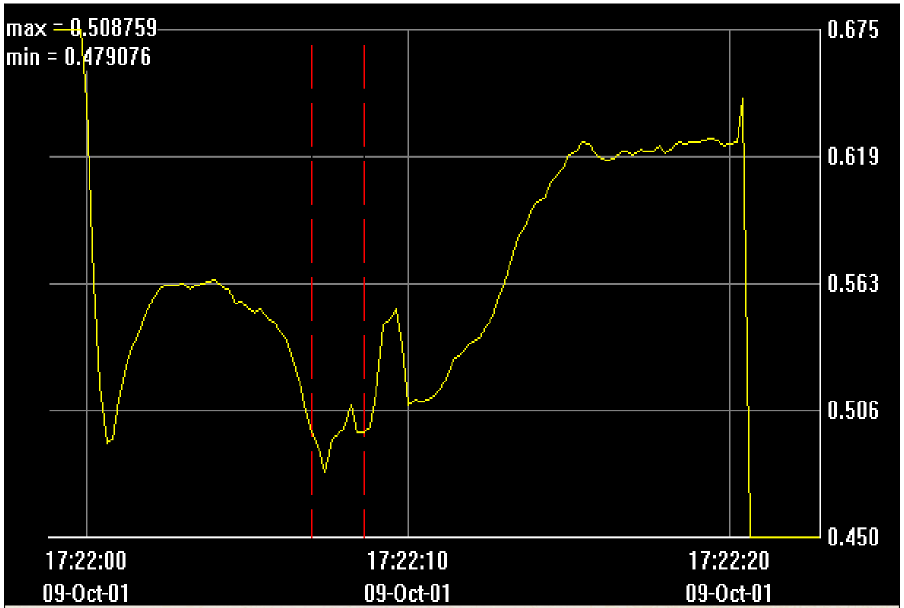
Signal from corrosion



menu

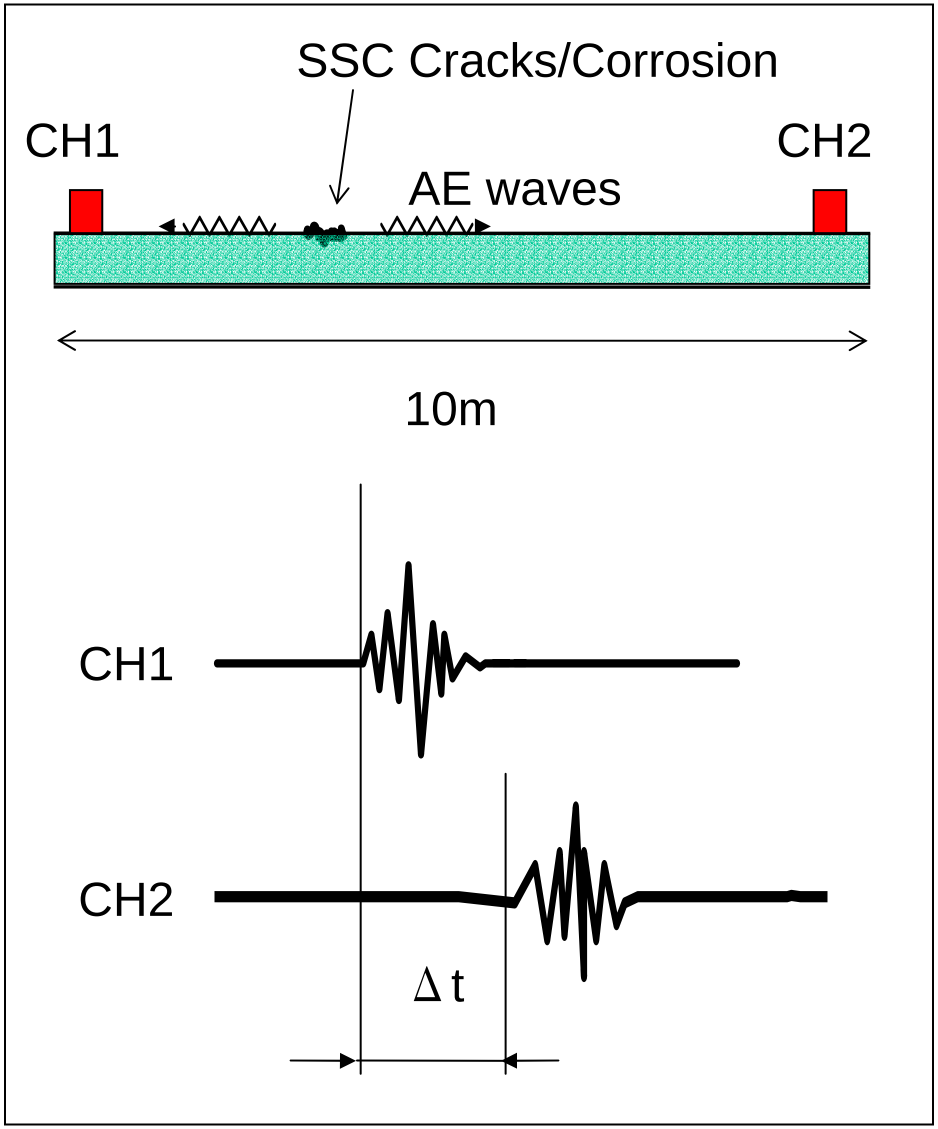
Lixi Profiler

The Lixi Profiler is a real-time method designed to rapidly assess density variations along a diameter of a pipe. The system plots a graph of "thickness" through the pipe diameter as the C-arm is manipulated along and around the pipe. Insulation removal is not necessary to utilize this technique, but the density must not exceed 1.5" steel equivalency.



Acoustic Emission

Acoustic Emission (AE) is an excellent method for the detection and location of SCC and active corrosion. AE "listens" to the noise generated by the propagation of cracks and the spalling of ferrous oxide. Location is determined by measuring the time differential of the sound waves reaching each passive transducer.



Computed Radiography

Computed Radiography is replacing conventional radiography for a number of reasons:

- **No chemical processing is required**
- **Wide latitude means substantially reduced re-shots**
- **Images are digital and therefore easier to transport and store for longer lengths of time**
- **Images are easily manipulated with software to enhance interpretation**

Keys to Achieving a Successful Mechanical Integrity Program

A viable MI program will withstand the scrutiny of outside regulatory agencies and provide internal process benefits in the areas of safety, reduction in unscheduled down time, reduced maintenance costs, and increases in profitability. Knowing the true condition of process equipment allows for proactive measures to be employed to minimize maintenance costs and to schedule repairs at convenient times; instead of at unscheduled times when increased costs will be incurred for expedited repairs and additional labor expenditures.

Keys to Achieving a Successful Mechanical Integrity Program

Preliminary Activities:

a. Adequately define the scope of work for specific process areas, equipment and circuits.

b. Determine most likely or anticipated damage mechanisms. This may (should) involve an Engineering evaluation of the process including material properties of process equipment

c. Define roles and responsibilities of NDE personnel and client personnel involved in the MI effort.

Keys to Achieving a Successful Mechanical Integrity Program

Establish an Inspection Plan:

a. Define where and when specific NDE techniques are to be applied
b. Define acceptance criteria for each NDE method
c. Determine level of qualifications of personnel to conduct the inspections
d. Include in the plan a mechanism to alert supervisory personnel of non-compliant equipment according to established acceptance criteria
e. Consider utilizing software specifically designed to manage and trend inspection data in order to evaluate detrimental mechanisms that may not be readily apparent from isolated and discreet inspection activities
f. Ensure all participants are trained in and follow established site safety procedures and protocols

Keys to Achieving a Successful Mechanical Integrity Program

Conduct the Inspections:

a. Acquire any necessary work permits (hot work, confined space, entry, etc.)
b. Conduct a Job Hazard Analysis (JHA) prior to conducting any inspections
c. Utilize accepted procedures for each NDE method
d. Utilize consistent reporting formats to ensure all necessary field data and equipment data is acquired
e. Utilize only properly calibrated NDE Equipment
f. Remain vigilant in awareness of any items appearing out of normal expectation and commit these findings to the written report

Keys to Achieving a Successful Mechanical Integrity Program

Report all findings in a written/electronic format that includes specifically:

a. Item Inspected and "as-inspected" condition (Clean, corroded, insulated, etc.)
b. Compliant/Non-compliant with acceptance criteria
c. Procedure utilized including revision numbers and dates
d. Date(s) of inspection
e. Name of responsible technician; Qualification Certification(s)
f. Name of Client and PO number
g. Any notable discoveries identified during the inspection which may not be specifically addressed in the inspection procedure
h. NDE Equipment utilized including serial number(s) and calibration due dates
i. Identifying numbers of any inspection consumables which were utilized during the inspection
j. Any "as-constructed" equipment information including U-1 forms, drawings, etc.

Keys to Achieving a Successful Mechanical Integrity Program

Data Analysis:

a. Determine next inspection interval
b. Modify likely damage mechanisms based on recent inspection findings
c. Establish Long Term and Short Term corrosion rates
d. Establish remaining life estimate
e. Select representative locations to monitor on a closer-interval basis to ensure validity of data projections

Why should you initiate an MI Program?

A facility in possession of Anhydrous Ammonia in excess of 10,000 pounds is covered under the PSM standard 29 CFR 1910.119

Furthermore, if a facility is in possession of 500 pounds or more of ammonia, per EPA 40 CFR Part 355, they must notify the Local Emergency Planning Committees (LEPC's) or State Emergency Response Commissions (SERC's) per the Superfund Amendments and Reauthorization Act (SARA) of 1986.

The goal of the above standards is to be prepared for potential releases that may affect employees and communities. An effective MI program reduces the risk potential of leaks.

How should you initiate an MI Program?

In the “cost sensitive” corporate environment we all live in today, it is very important to realize that a low price does necessarily mean low cost; in fact, most of the time price is inversely proportional to overall cost. An analogy is the stock market and Return on Investment (ROI). An investment requires seed capital which provides for increased overall value over time. The more capital invested, the more overall value is accumulated over time. A minimal initial investment yields minimal increased value. In this analogy, the minimal initial investment relates to a low cost evaluation of your process equipment and will yield minimal, if any, increased confidence in the fitness-for-service condition of the process equipment.

How should you initiate an MI Program?

An adequate, and necessarily higher, cost of evaluation will yield a much higher ROI and therefore increased value to the client. The value and overall cost savings result from the fact that the process equipment, when adequately assessed, will extend run times of the equipment, will allow for pre-planned repairs and replacements of process components, and enable significant improvements in budgeting accurate costs for the maintenance of the process equipment. The result is lower overall costs attributable to initial adequate spending and appropriate maintenance spending over time.

Standards Affecting Ammonia Possession

OSHA - HAZCOM – 29 CFR 1910.1200

OSHA - HAZWOPER – 29 CFR 1910.120(q)

OSHA – PSM – 29 CFR 1910.119

Article (j) is Mechanical Integrity

EPA – Emergency Planning & Notification - 40 CFR Part 355

Tab 6

Mechanical Integrity Field Experiences

Godan Nambudiripad:
General Mills

November 9 – 10, 2004
The Pyle Center, Madison, WI

MI
An Industry Experience

November 10, 2004

Godan Nambudiripad

GENERAL MILLS

Context:

What would you tell your CEO about NH3 safety?

- Exploding boilers made safe by ASME codes 100 years ago
- Electricity made safe by NFPA national electrical code 80 (?) years ago
- Focused attention to ammonia safety started a few decades ago

GENERAL MILLS

Business Rationale:

- MI is a program to improve reliability and safety
- MI proactively addresses situations that could release ammonia
- Ammonia release creates unsafe situations for people and property

GENERAL MILLS

General Mills Approach to MI:

- For MI of Mech. Equip. follow Mfgr's Recommendation
- IIAR Bulletin 109 gives some guidance for piping and vessels
- Bulletin 109 is good but insufficient for piping and vessels
- The basis and approach explained in IIAR 2004 Conference paper by Ron Cole and Godan Nambudiripad

GENERAL MILLS

Basis for General Mills MI program for piping and vessels:

1. Major cause of failure of Piping and Vessels recognized: external surface corrosion
2. Location of corrosion – where moisture is present (freeze thaw cycle, cold)
3. Stress Corrosion – not much experience in refrigeration, less catastrophic
4. Internal Corrosion due to erosion – high velocity wet return

GENERAL MILLS

General Mills MI program for piping and vessels:

- **Monitor –** routine
- **Inspect –** annual OR resulting from observation or event
- **Test –** 5-year OR as indicated by inspection

GENERAL MILLS

MI for Piping and Vessels:

1. Inspect every 100 ft. and each section of piping that can get wet
   a) Freeze thaw
   b) Cold but above freezing
   c) hot gas piping in cold rooms
   d) Defrost return lines
   e) Vessel fill lines
2. Inspect Cold Vessels operating in 32º F – 60º F.
3. Inspection interval every 5 years

GENERAL MILLS

Results of field inspection:

- (All plants had applied Bulletin 109 in the past)
- 30 % plants identified potential issues
- Within a year another type of piping was identified piping which were originally thought to be frozen, but in real life experiences freeze thaw cycle due to non-continuous operation of the process

GENERAL MILLS

Incorporating MI learning's into design:

- Add piping protection to pipe in wet region – grease tape, surface modification etc.
- Consider the use of SS piping
- Improve insulation (especially vapor retardant) specifications & quality control of the installation

GENERAL MILLS

Next Steps

- Learn more from refrigeration industry
- Review inspection results and failures (internal)
- Improve the piping and insulation installations – work with industry

Conclusion

RECAP:

- **Business need for MI**
- **Developing NH3 specific MI for piping & vessels**
- **Learnings from rolling out company wide**
- **Incorporating MI learnings into installations**
- **Next steps in developing NH3 specific MI**

THANKS !

GENERAL MILLS

For Additional Information

- **For additional information see the paper:**
  - ***Mechanical Integrity for Ammonia Refrigeration System Piping and Pressure Vessels***

    By Ron Cole and Godan Nambudiripad
  - **Presented at the 2004 IIAR Ammonia Refrigeration Conference in Kissimmee, FL**

GENERAL MILLS

Tab 6

Mechanical Integrity Field Experiences

Bent Wiencke: Nestlé

November 9 – 10, 2004
The Pyle Center, Madison, WI

Example of an End-User Ammonia Safety Audit Program

Bent Wiencke – Nestlé USA

November 10, 2004

Legal Disclaimer!

This presentation and its content is for informational purposes only.

Background

The NH3 Safety Audit program was initially developed in 1987 with internal resources in an effort to:

- Prepare Nestlé factories for the upcoming phase-out of CFC's and subsequent conversion of existing CFC systems to ammonia and phase-in of new ammonia systems.
- Prevent and reduce ammonia related accidents.
- Prevent and reduce ammonia losses.
- Prevent and reduce production downtime caused by unreliable ammonia refrigeration systems.
- Prevent and reduce impact on neighborhood, environment, etc. caused by ammonia related incidents.

Background (cont'd)

Initial audits were done using photo-copied templates, which were at a later point transferred to an Excel spreadsheet. Using Excel was an improvement, but shortcomings were still evident:

- Very tedious data entry.
- Audits of large ammonia refrigeration systems produced 1500+ handwritten pages, which required to be transferred to an Excel spreadsheet.
  - Errors were often introduces in final document.
- Final document was submitted 3-4 month after audit was conducted.
- Post audit follow-up was very difficult and tedious with factory that had 500+ recommendations.

Background (cont'd)

In 2003 Excel document was converted to an MS Access database program, which brought numerous advantages:

- Each auditor enters her/his own data and initials each data entry → accountability.
- MS Access allows all auditors to work simultaneously with the same database.
- Final audit results can now be submitted at the end of the audit and not 3-4 month later.
- MS Access allows the generation of reports, which simplifies post-audit follow-ups.
- Information can be entered by factory prior to audit.

Why do we audit? What is its purpose and value?

The underlying aim of the Nestlé ammonia safety audit is safety:

- Safety of employees, the general public, products, facilities and the environment.

“This audit and our ongoing, day-to-day ammonia refrigeration performance standards and tools that complement it enable us to build, operate and maintain all ammonia refrigeration systems with minimum risks and maximum efficiencies and benefits to our overall operations.”

Why do we audit? What is its purpose and value?

For these reasons, the audit must specifically:

- Pinpoint actual and potential safety hazards related to design, location, operation and maintenance of ammonia refrigeration plants.
- Identify ammonia safety regulatory requirements and gather information to help determine performance against them.
- Provide an objective means to assess and document the continuing ammonia safety of our facilities.

Why do we audit? What is its purpose and value?

- Provide an objective means of defining and identifying needs for any upgrades, additions and/or modifications to the facility and operations in relation to refrigeration systems. Assist in documenting and providing justification for expenditure in these areas if required.
- Provide feedback on facility safety issues associated with ammonia operations and/or related activities so that information may be shared with other affected or involved functions and acted upon as needed.
- Serve as a guide for the assessment of safety of new ammonia installations.

Why do we audit? What is its purpose and value?

The ammonia safety audit is NOT:

- A tool for comparing ammonia safety standards among or between facilities.
- A tool to be used as an overall measure of general safety management competence.
- A tool for team members to draw legal conclusions in relation to regulatory or compliance components.

What is expected of audit team members?

Audit team members are to :

- Fully act as experts, counselors and assessors in their particular technical, functional and/or facility specific areas during the audit .
- Provide appropriate implementation and action plan input to the audit and during the audit findings review with the facility.
- Serve as post-audit team members and leaders for implementation of audit action plan.
- Serve as post-audit team members and leaders for those on-going ammonia system operations and activities related to their specific expertise that will ensure optimal and continued system performance.

Who is conducting the audit?

Full-time members of on-site audit team:

- Facility Level
- Engineer
- Refrigeration Engineer
- Safety Manager
- Maintenance Manager
- Shared Services/Corporate Functional Level
- Refrigeration Engineer/Manager
- E&S Manager/Division Liaison

Responsibility of Audit Team Leader:

One member of the on-site audit team will serve as overall audit team leader. This leader will:

- Facilitate needed team activities, input and discussion.
- Determine and ensure involvement of other functional experts (legal, etc.) as issues arise during audit.
- Coordinate the audit findings and creation of the audit report.
- Serve as primary spokesperson and presentation coordinator of the team's audit results discussion and review with the facility manager at the audit exit interview.

Responsibility of Audit Team Leader:

- Ensure a timely release and distribution of the audit report and the facility's subsequent action plan as appropriate to key functions outside the factory (legal, SOM, etc.).
- Ensure regular follow-up with and reporting from the facility on audit progress or needed support. Coordinate such support.

Function-Specific Involvement

- Facility Level
- Facility Manager - Audit Kick-off and Audit Findings Review; General Implementation Support, Review, Assessment.
- Other functions - as appropriate per audit findings or eds and/or facility manager's request.
- Shared Services/Corporate Functional Level.
- SOM - Awareness of audit findings, general support.
- Legal - Awareness of audit findings, regulatory/compliance interpretation/determination as needed.
- Engineering, E&S, Finance, Maintenance, etc. - Awareness of audit findings, general support, further action as appropriate based on audit findings or needs.

General Management Support

- The auditing process requires significant staffing and time commitments, both at facility and shared services functional levels. It also can result in increased capital and maintenance costs and/or longer-term staffing and time commitments - not only to act upon the findings but also to ensure on-going, safe performance of the ammonia system.
- On certain occasions, it may also result in the need for fundamental and/or strategic decisions on the continued operation of the refrigeration plant.
- For these reasons, audits must have the support of management - especially technical management - at all levels.

Audit Findings

- Audit sections and questions have been organized to reflect key areas for the safety of ammonia systems.
- Many questions are included to record facility information for reference by the audit staff during the process and by facility staff in the future.
- The audit team must judge the degree of performance being addressed in each question and assign a Safety Item Rating (SIR) to it. The definitions of the SIR's and when and how they must be addressed are as follows:

Audit Findings – Definitions

E: Emergency

- Definition: Situation is so severe that there is immediate risk to employees, facility or neighborhood.
- These can be physical or organizational.
- Physical - i.e.: bad corrosion; relief valves missing.
- Organizational - i.e.: issues which may contribute to rapid deterioration of the plant or the inability to safely deal with an incident. For example - lack of staff capable to deal with specific issues and situations of the facility, no emergency plan, inadequate safety equipment, etc.
- When and How to Address: Must be addressed/fixed before audit team leaves the site. All team members and needed facility staff work to that end as needed.

Audit Findings – Definitions

U: Urgent

- Definition: Situation or condition appears to be serious or potentially hazardous but not necessarily an immediate risk to employees, facility or neighborhood. Situation or condition raises possible regulatory questions and should be thoroughly evaluated concerning code and compliance requirements.
- When and How to Address: A firm and timely deadline and action steps must be set ASAP to review and act upon the situation. Should not wait for actions and timing to be addressed for the first time in the facility's audit action plan.

Audit Findings – Definitions

I: Improvement

- Definition: Situation or condition must be addressed to result in increased performance and efficiency and to ensure meeting of prudent and/or good recommended industry practice.
- When and How to Address: Action needed can be achieved through regular channels of maintenance, capital improvements or assignment to facility or functional staff. Can wait for actions and timing to be addressed in facility's audit action plan. The facility's audit action plan must be completed and shared with the audit team no longer than two weeks following the completion of the audit.

Audit Findings – Definitions

N: Normal

- Definition: Situation or condition as it should be.
- When and How to Address: No action considered necessary. Where appropriate, the audit team should include notes in audit explaining why no action is considered necessary.

N/A: Non Applicable

- Definition: Does not apply to specific location.
- When and How to Address: N/A

R: Recognized Practice

- Definition: A good or excellent practice that the audit team wants to take notice of.
- When and How to Address: N/A

Audit Process Instructions

General guidelines, interview techniques and audit comments that ensure the most valuable audit:

General Guidelines:

- Be factual.
- Avoid unsubstantiated conclusions.
- If potential or suspected compliance issues or sensitivities arise, discuss with the team leader and get the E&S attorney involved.
- Keep team informed.
- Solicit input from other team members.

Audit Process Instructions

If Conducting Interviews or Soliciting Input or Information:

- Respect your fellow employees, their roles and their knowledge Ease into the discussion, do not start abruptly.
- Take notes of key points.
- Listen carefully and do not hesitate to ask a question again if the answer is unclear.
- Avoid making assumptions.
- Avoid leading questions.
- If the situation allows, ask open-ended questions (i.e. - "what, how, etc." rather than "yes/no").
- Maintain eye contact.

Audit Process Instructions

If Conducting Interviews or Soliciting Input or Information:

- Avoid confrontational situations and arguments.
- Avoid "us vs. them" settings.
- Avoid seemingly accusatory questions.
- Tolerate and respect silences.
- Portray a feeling of comfort and trust.
- Summarize key points.
- Appreciate and acknowledge the person's contributions to the process.
- End on a positive note.

Audit Process Instructions

When Creating/Making Audit Comments:

- Do not draw legal conclusions. Avoid using words and phrases such as "compliance," "violation," "illegally,“ "incompetent," "criminal, "intentional,“ "dangerous," "reckless," "fraudulent," etc.
- Keep in mind that your notes may be subject to public disclosure.
- Avoid generalities. Do not use words like "poor," "inadequate," "alarming," etc.

Audit Process Instructions

When Creating/Making Audit Comments:

SAY:	INSTEAD OF:
“The facility's contingency plan lacks the following elements:”	"The facility's contingency plan is inadequate“.
“Last year, the facility did not file an "X" of…” (give reg. citation if applicable)“	"Last year, the facility violated the requirements“.
“We were unable to determine that…”	"This facility does not have…“
“It appears that…”	"We found that…"
“An exception was found in regard to…”	"This facility is non-compliant in regard to…"
“Consider” or “Should”	"Must" or "Shall"

10+ Years Experience from US Market

Initial Obstacles and Reactions:

- Skepticism!
- Limited upper management support.
- Concerns that “Dirty Laundry” will be exposed!
- Cost of audits!
- Cost impact of findings!
- Resources!
- Legal implications if deficiencies are disclosed.
- “I am the expert here, who in the hell are you?”
- “We need no stinking audit in my plant!”

10+ Years Experience from US Market

Today's Status:

- Significant reduction in deficiencies.
- Buy-in from upper management!
- Very good ammonia safety record!
- Creates good "cross fertilization" by using utilities engineers from other plants as auditors.
- Safety audit program satisfies PSM/RMP MI requirements and is well received by Authorities Having Jurisdiction.
- Audit findings are used as a justification to upgrade refrigeration system and commit additional resources.
- Auditors feel privileged to be invited to an audit.

10+ Years Experience from US Market

Today's Status (cont'd):

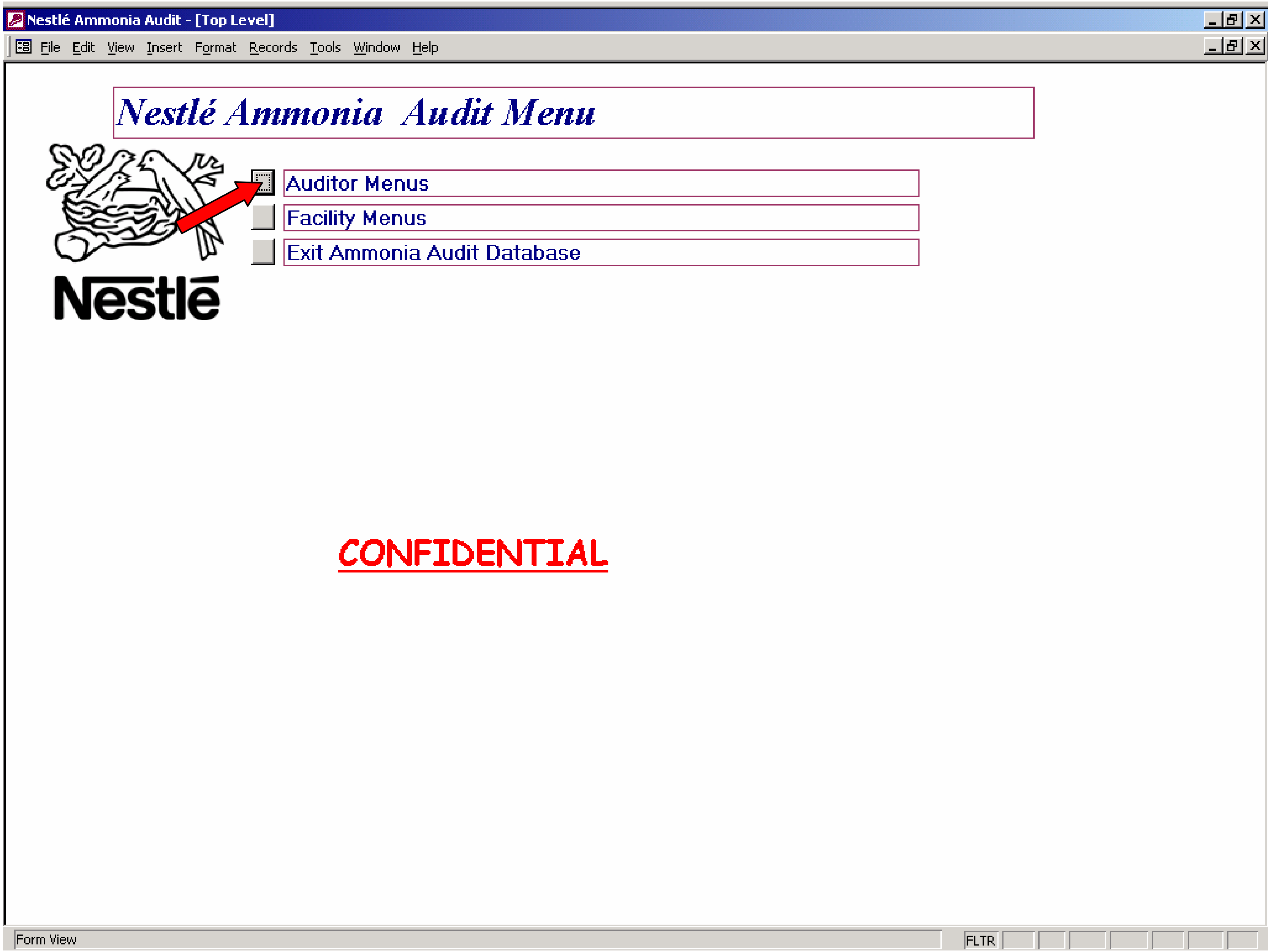
- Ammonia Safety Audit Program is well received by management and plant personnel.
  - ✓ Audit frequency has been increased from 5 years to 3 years in most divisions → because it is not only being used as an audit tool.
- Better reliability of ammonia refrigeration system.
- Better efficiency of ammonia refrigeration system.
- Until 2003 all ammonia safety audits were conducted under the directive of Nestlé's legal council and all communication was done under "Attorney Client Privileged Information".

10+ Years Experience from US Market

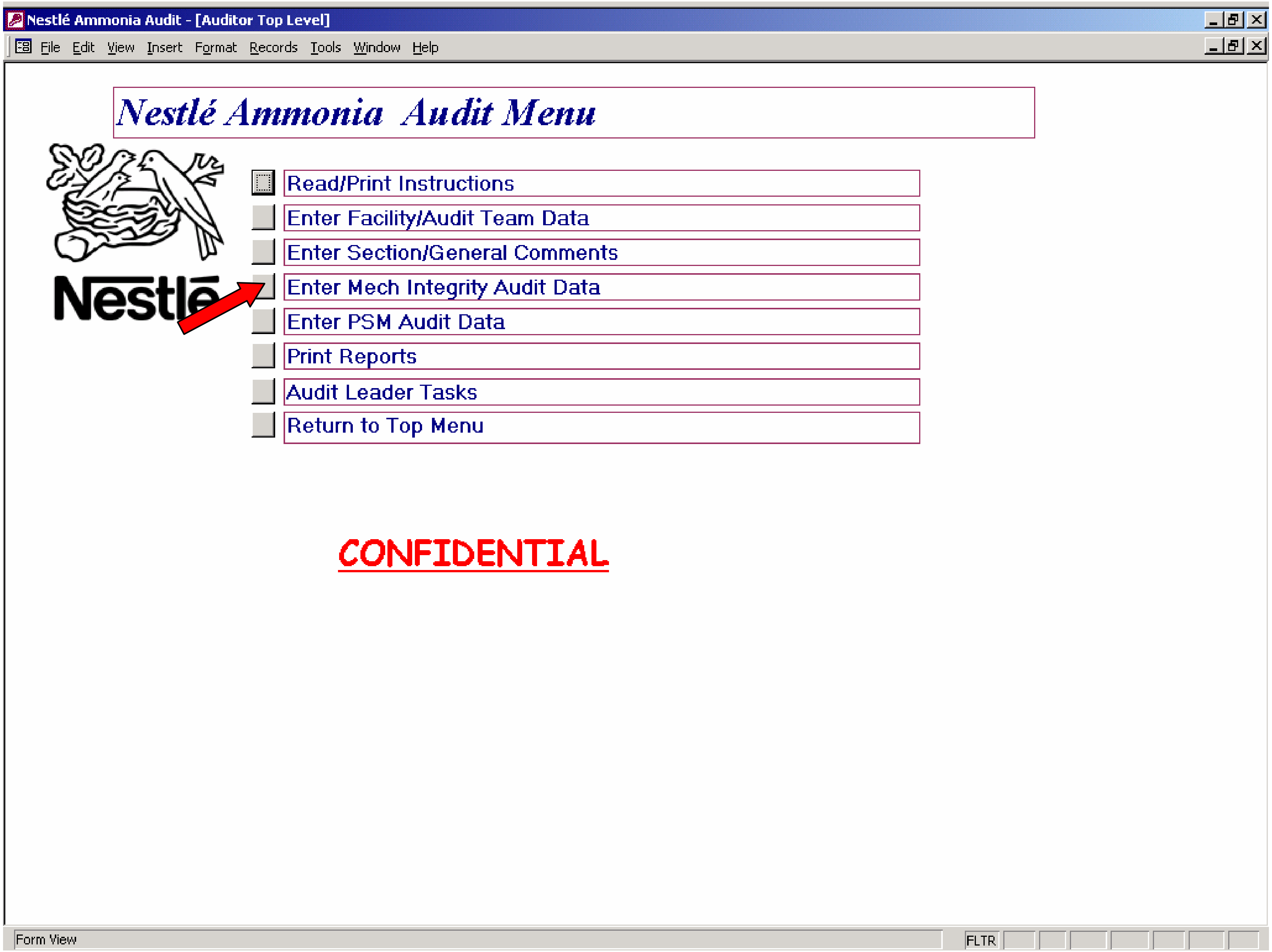
Challenges Still to Overcome and Opportunities:

- Resources!
- Most ammonia safety audits are conducted while the factory is in full production mode. This creates obstacles for the audit process:
  - Current "ammonia safety audit" program relies to a great extend on verbal communication and documentation, e.g.:
    - Testing of compressor safety cut-outs.
    - Testing of hard-wired safety devices such as high-level cut-outs'.
  - MI testing of pressure vessels, piping, valves, etc. relies on visual inspection and thermo-graphic measurements. Currently, there is no method in place to conduct any form of Non Destructive Testing (NDT).
- Expertise of Auditors.

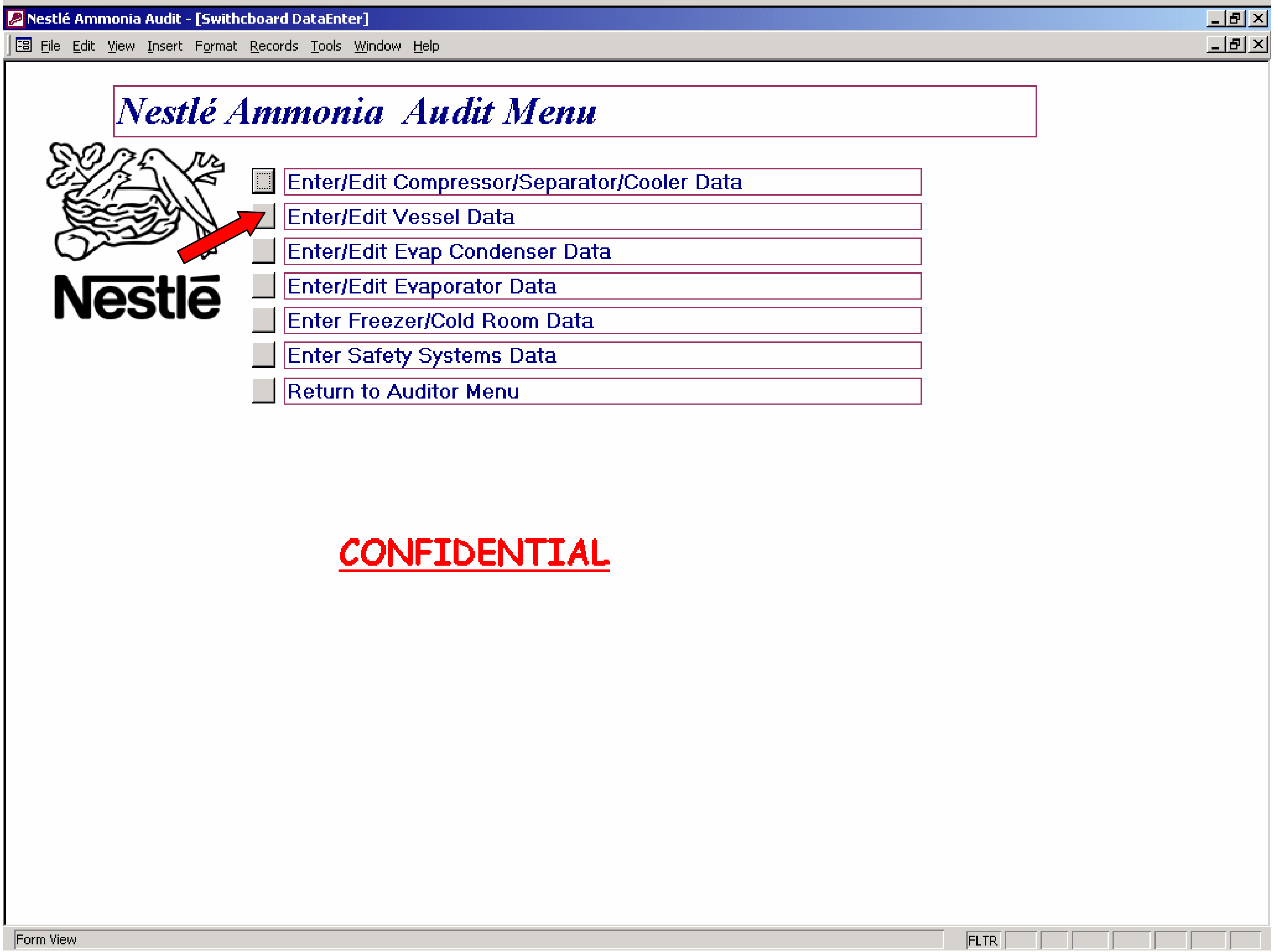
Sample Screenshot #1



Sample Screenshot #2



Sample Screenshot #3



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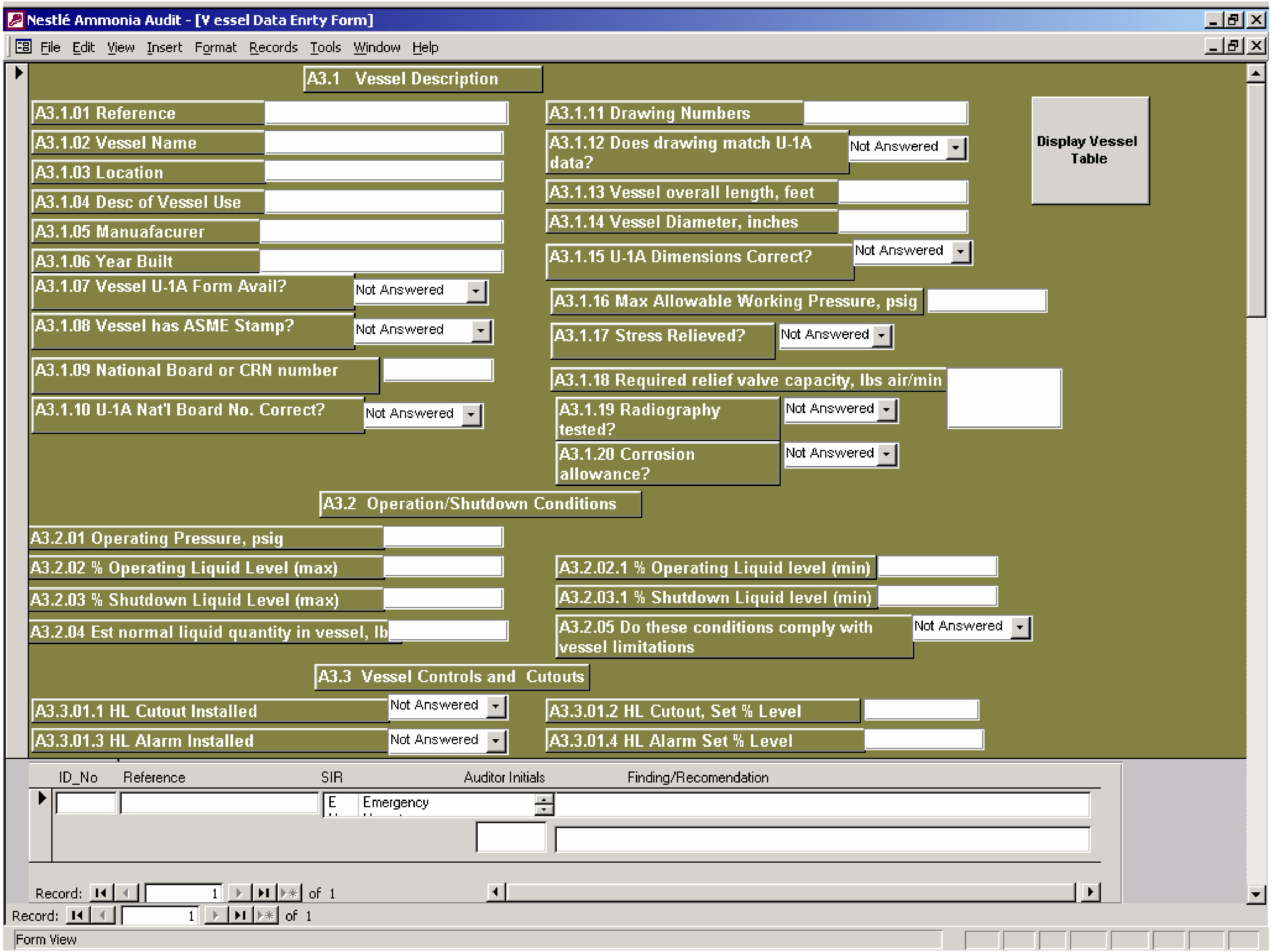

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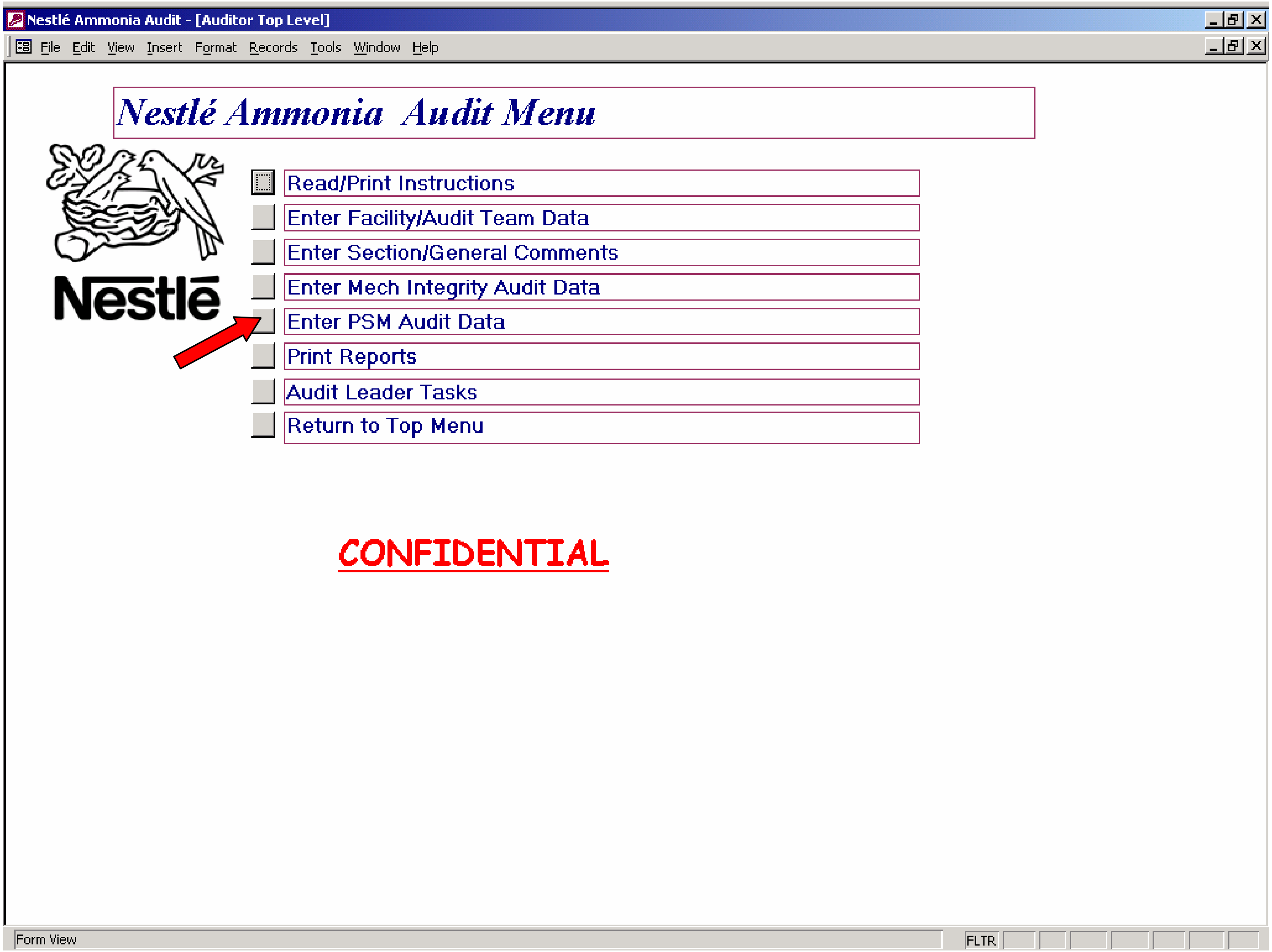

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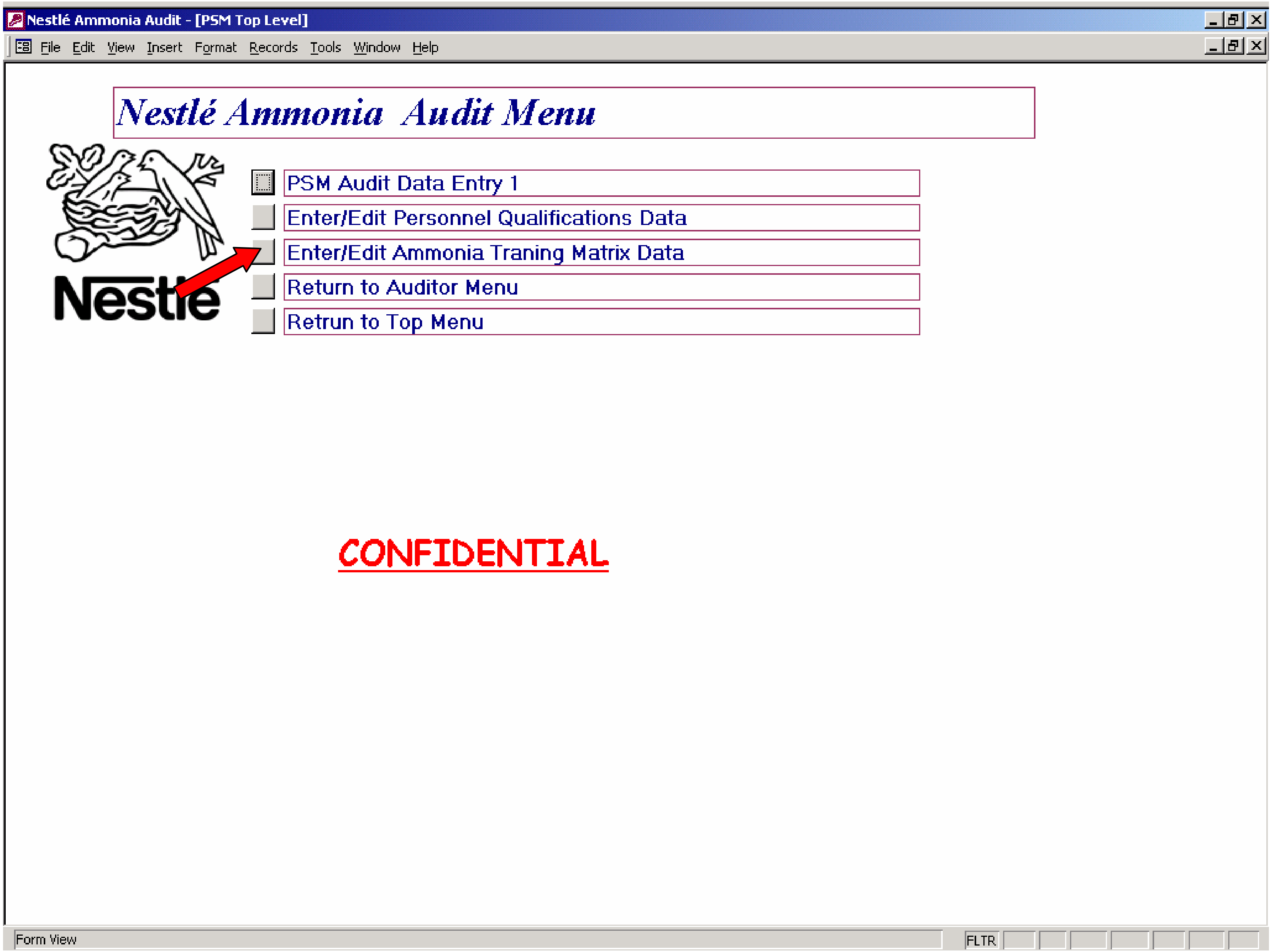

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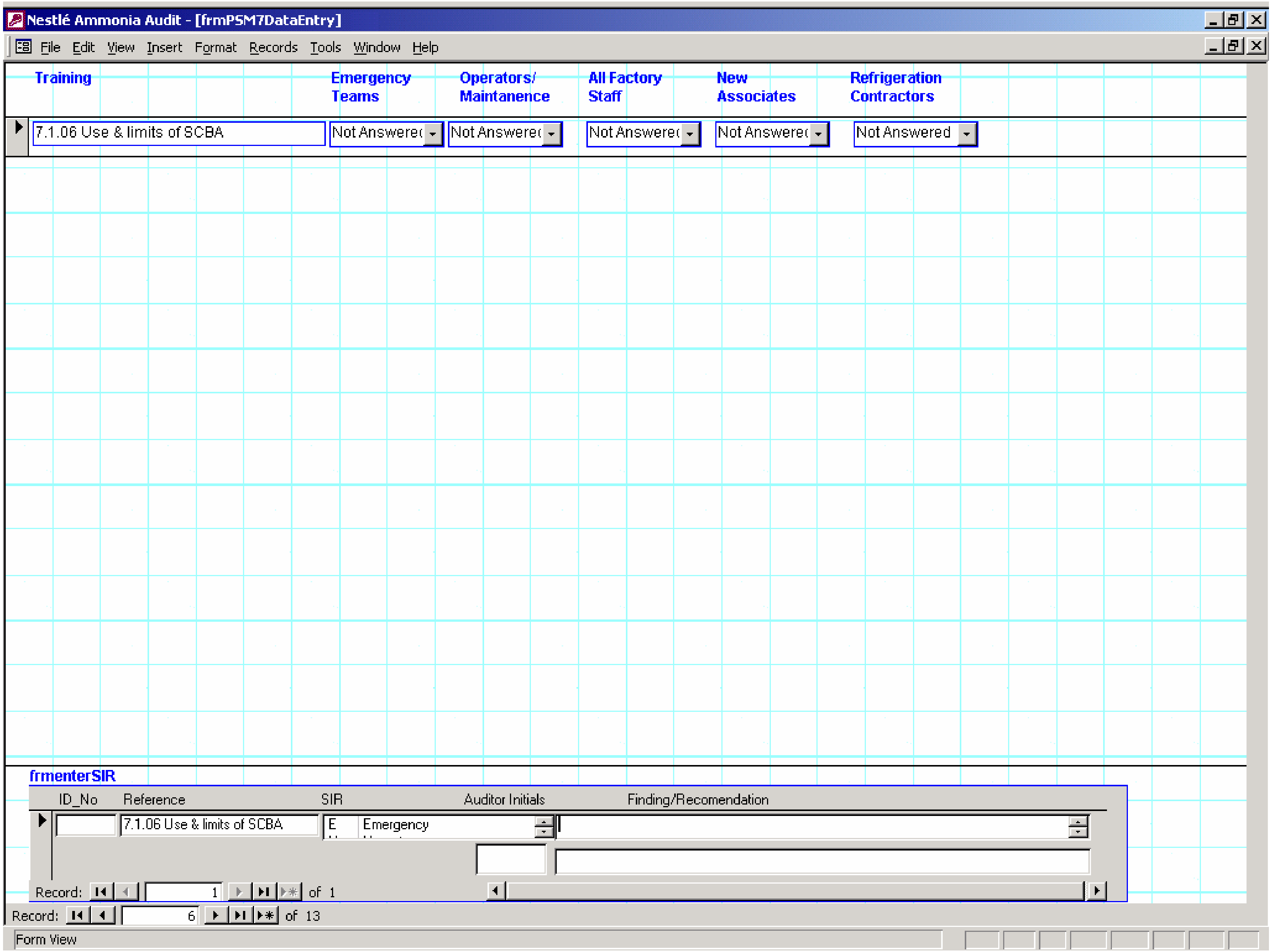

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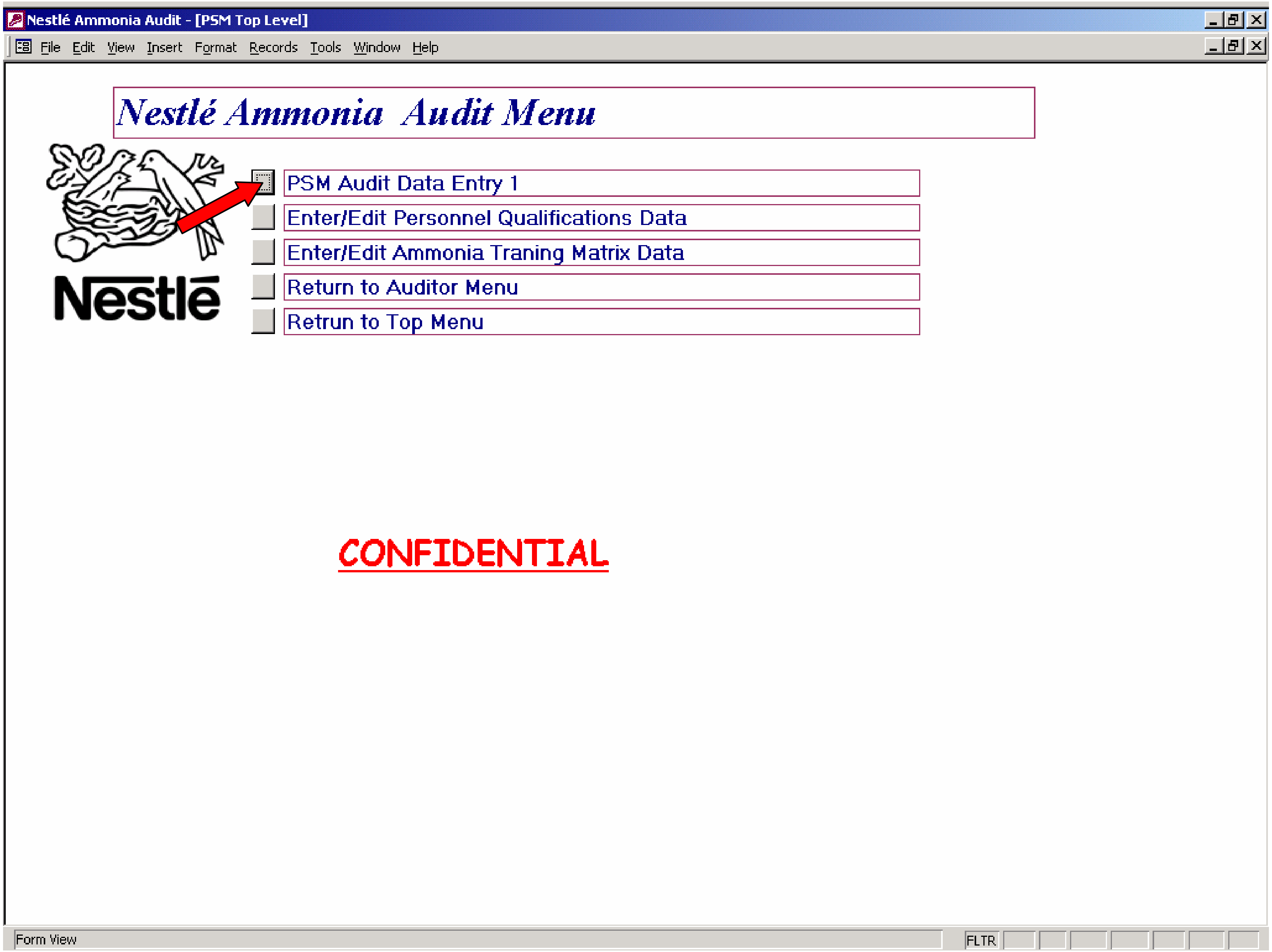
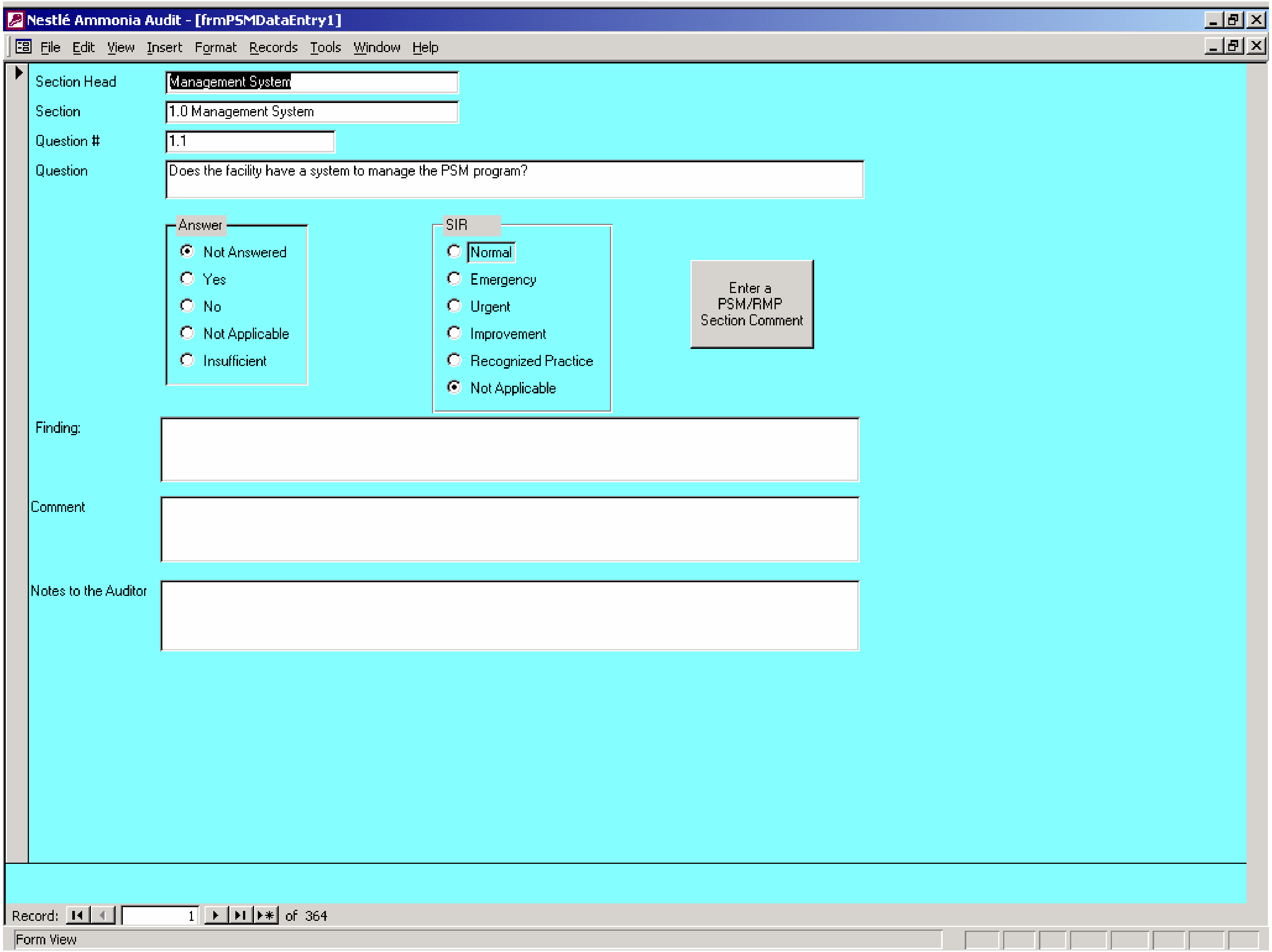
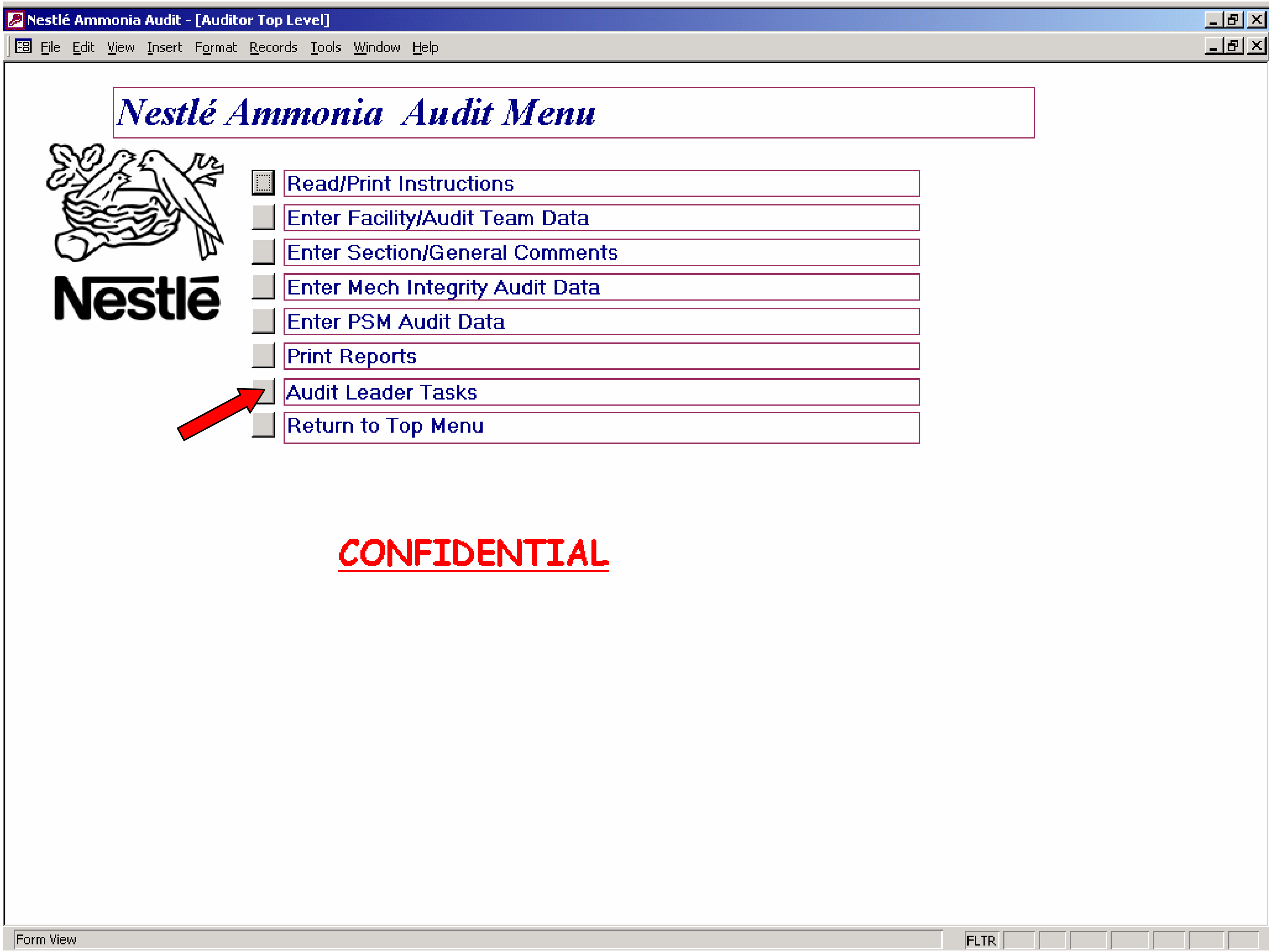


Sample Screenshot #9



Sample Screenshot #10



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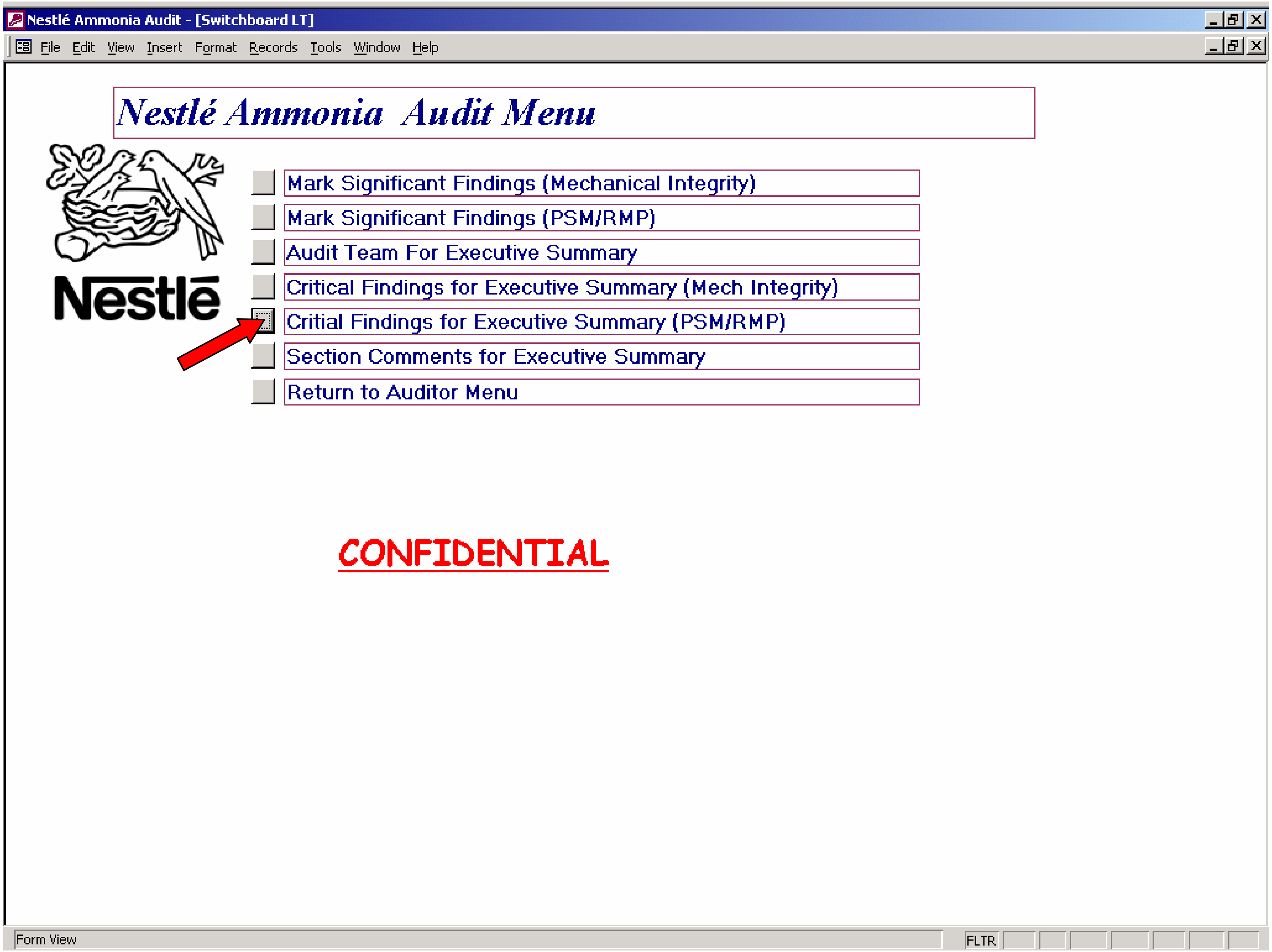

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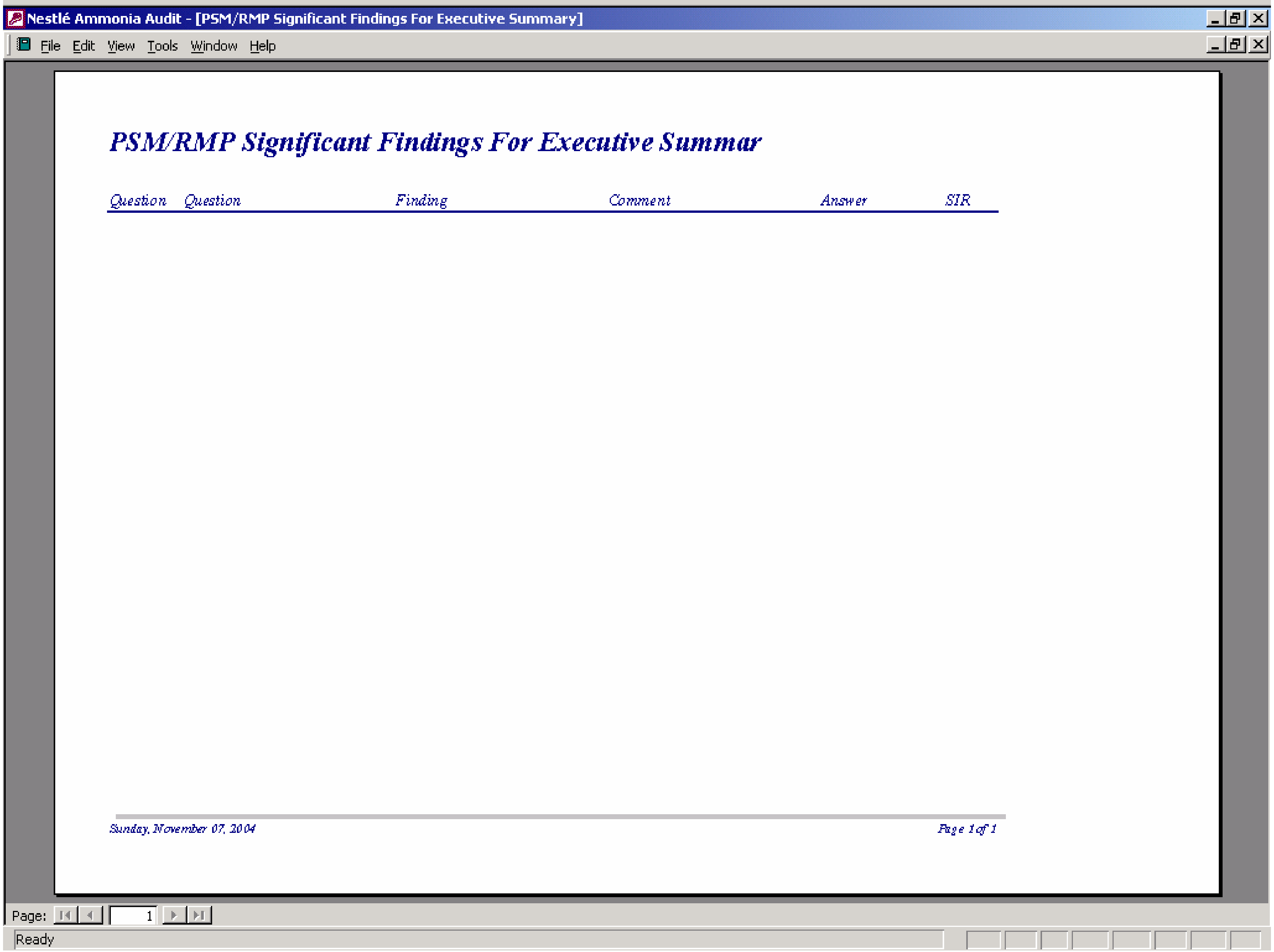

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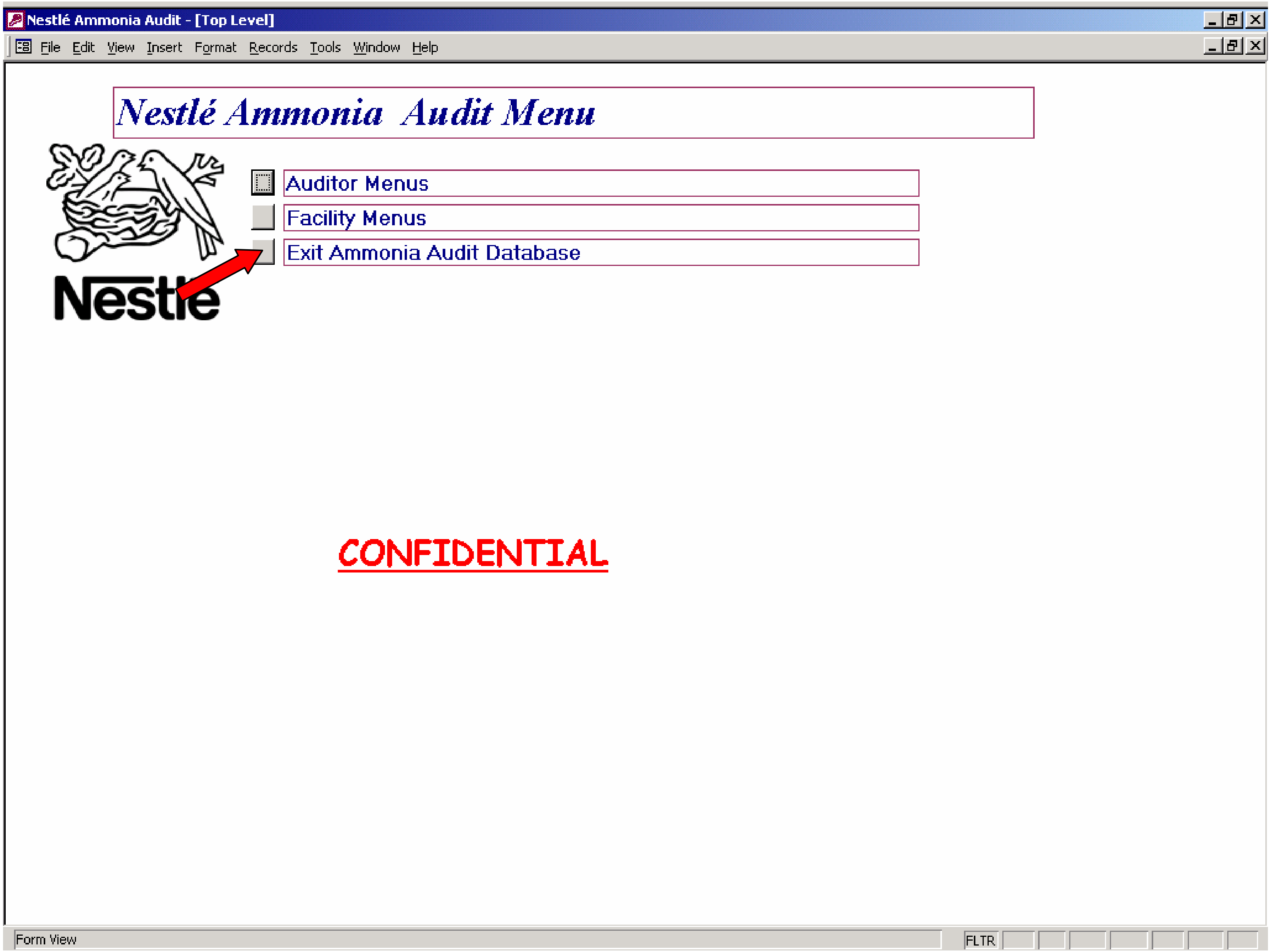


Questions??

Comments??

Thanks!!!

Incident Investigation of a Ruptured Ammonia Pipe at a Frozen Food Factory

Bent Wiencke – Nestlé USA

November 10, 2004

Legal Disclaimer!

This presentation and its content is for informational purposes only.

Detailed Description of Release

- Date and time: January 18, 2004 at 3:30 PM.
- Amount of ammonia released: Approximately 225 lbs.
- Estimated release duration: 45 seconds
- Number of people in release area: 0
- Number of people injured: 0
- Amount of product contaminated: 0
- Production loss: 1.75 shifts, total of 7 lines due to excessive air infiltration into ammonia system.

Detailed Description of Release

- ➔ **Release location: Spiral Freezer no. 7 valve group located in sub-ceiling**
- ➔ **Origin of release: pipe leak (ruptured pipe)**
- ➔ **Ammonia was released into: air**
- ➔ **Evacuation: none**
- ➔ **Notification of release: Authorities and everybody on emergency response team.**
- ➔ **Classification of ammonia leak incident: Class 3 – Minor *(An ammonia release requiring the use of breathing equipment to contain, but no injury to people; or damage to product, or environment)***

Description of Valve Group and Piping Design

The main valve group where the pipe rupture occurred is used in conjunction with spiral freezer no. 7 and is located in an interstitial space (sub-ceiling level) next to the very top level of the freezer. The main valve group consists of four (4) individual valve stations, each connected to individual air cooler coils located within the spiral freezer envelope. The valve stations are used to control the liquid supply during freeze mode, control the hot-gas supply during defrost cycle, and pump-out after defrost is completed. Each individual valve station is designed with a 4" suction line and a 4" automatic suction valve including a ½" bypass solenoid valve. The purpose of the ½" bypass solenoid valve is to bleed the pressure after defrost from defrost pressure (approximately 90 to 110 psig) to system suction pressure before the 4" main valve opens. The 4" main valve is a R/S Parker gas powered suction stop valve of the type CK-2 and it is normally open when not actuated. Two valve stations are located on the south side of the freezer and two valve stations are located on the north side of the freezer. Each 4" suction line is connected to a 6" main header. The individual 4" suction lines with 4" main valves and the 6" main header present the lowest point in the entire piping arrangement. From the 6" main header the ammonia gas/liquid flows through two 5' long suction risers to a second 6" main header. The second 6" main header is located 5' above the first 6" main header. From the second 6" main header, the ammonia gas/liquid gravity flows back to the low-pressure pump recirculator. Figure 1 shows a schematic of the valve group and piping arrangement.

Description of Pipe Rupture

As illustrated in Figure 1, the pipe rupture occurred right in the middle of the 6” main header at a weld. The total length of pipe affected by the rupture was 3’. The longitudinal main cracks occurred at a five o’clock position with some minor cracks occurring at the eleven o’clock position.

Figure 2 shows pictures of the ruptured pipe section.

Figure 1: Schematic of Valve Group

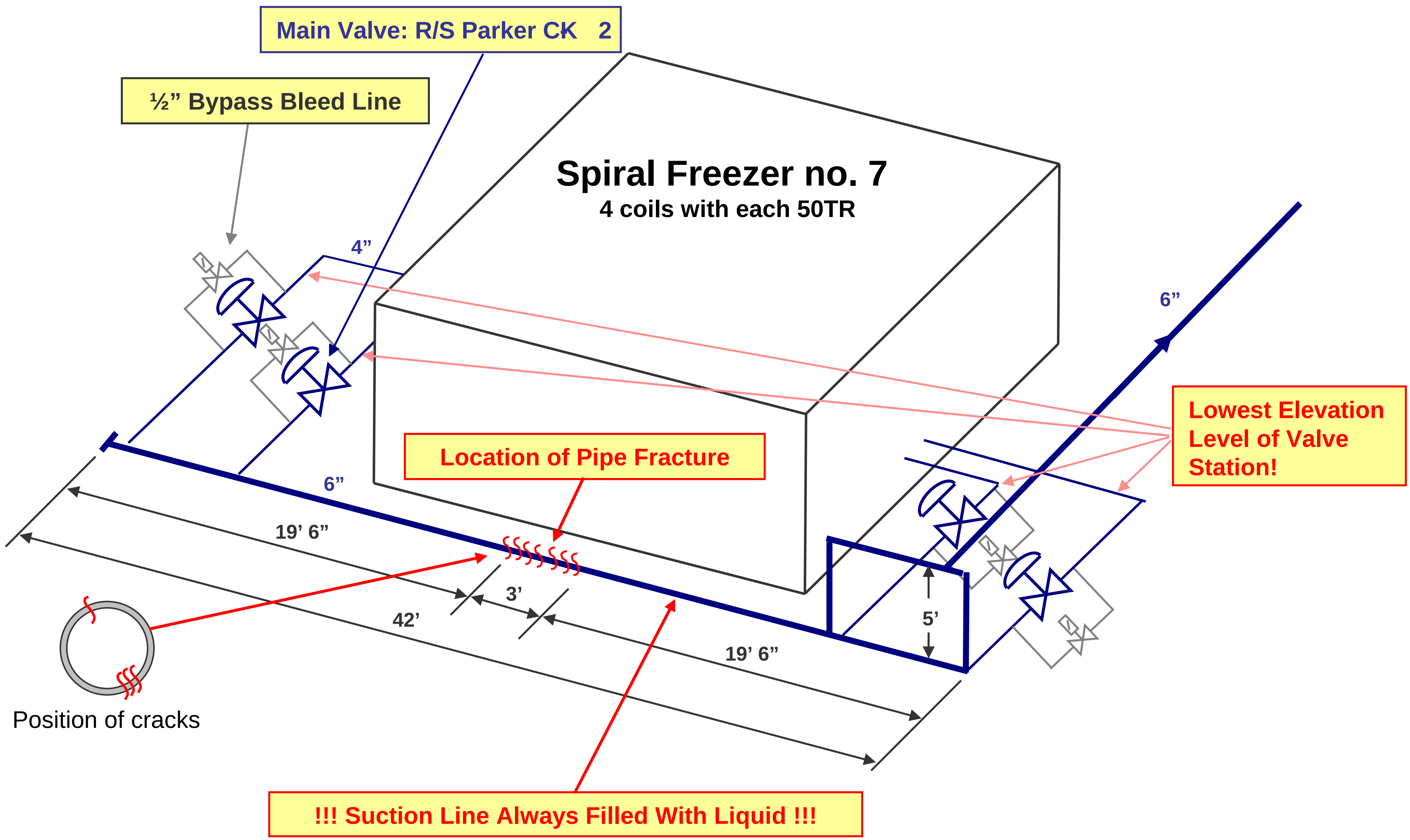


Figure 2: Pictures of Ruptured Pipe Section

Figure 2: Pictures of Ruptured Pipe Section (cont'd)

Incident Analysis

Based on the observations by the operators, the timing of events, the 6" main header configuration being prone to liquid trapping and the characteristics of the ruptured pipe, it is very likely that the pipe rupture was caused by "hydraulic shock" also known as "liquid hammer". Hydraulic shocks create extremely high pressure spikes, which can be in excess of 2000 psig. Extreme pressure spikes can be induced by various factors such as:

- Vapor bubbles collapsing
- Moving liquid coming to a rapid halt
- Liquid propelled by very high velocity vapor coming to a rapid halt

Incident Analysis (cont'd)

In this case it is very likely that vapor propelled liquid was the ultimate cause that led to the pipe rupture due to the factors discussed below. The event that initiated the hydraulic shock is open to question. Upon closer examination several contributing factors were identified:

- Main suction valve was not installed in accordance to the manufacturer's recommendation.
- Design and location of bypass bleed line makes it succestible to clogging with dirt, debris and compressor oil.
- Metallurgic test report revealed that "stress crack corrosion" was present were the pipe cracked. Crack started at the contact point between the *backing ring* and the pipe**.**
- Suction line is always filled with liquid.

Fig. 3: Functional Illustration of Main Suction Regulator

Hot gas introduced above piston force closes valve.

Internal bleed hole releases gas above piston downstream of valve, allowing the valve to open!

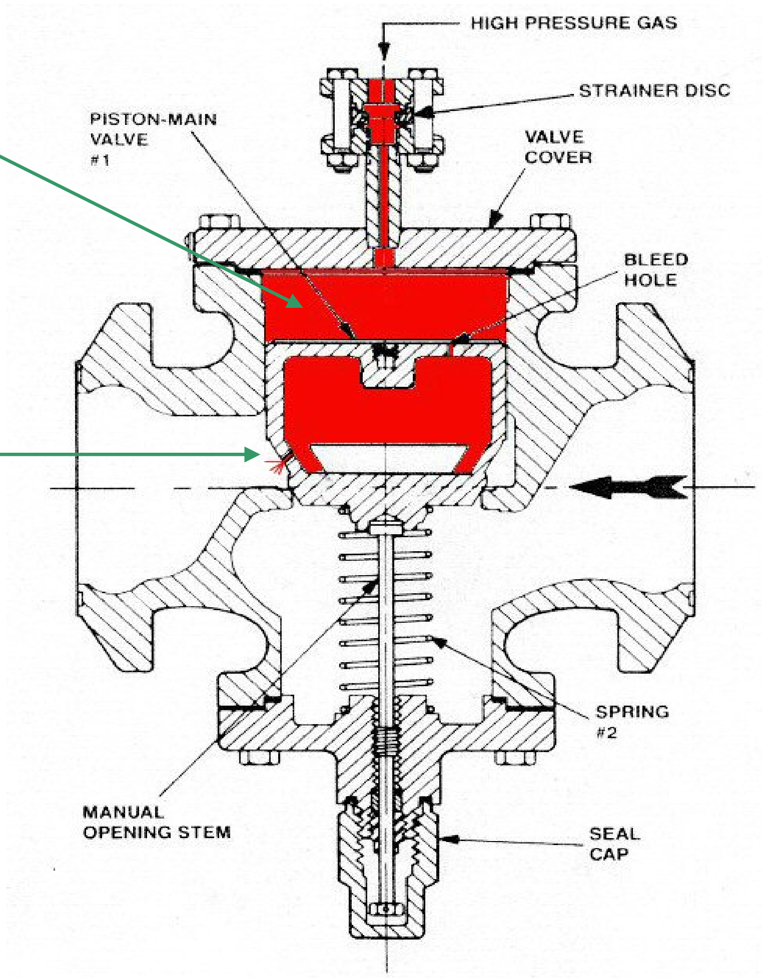
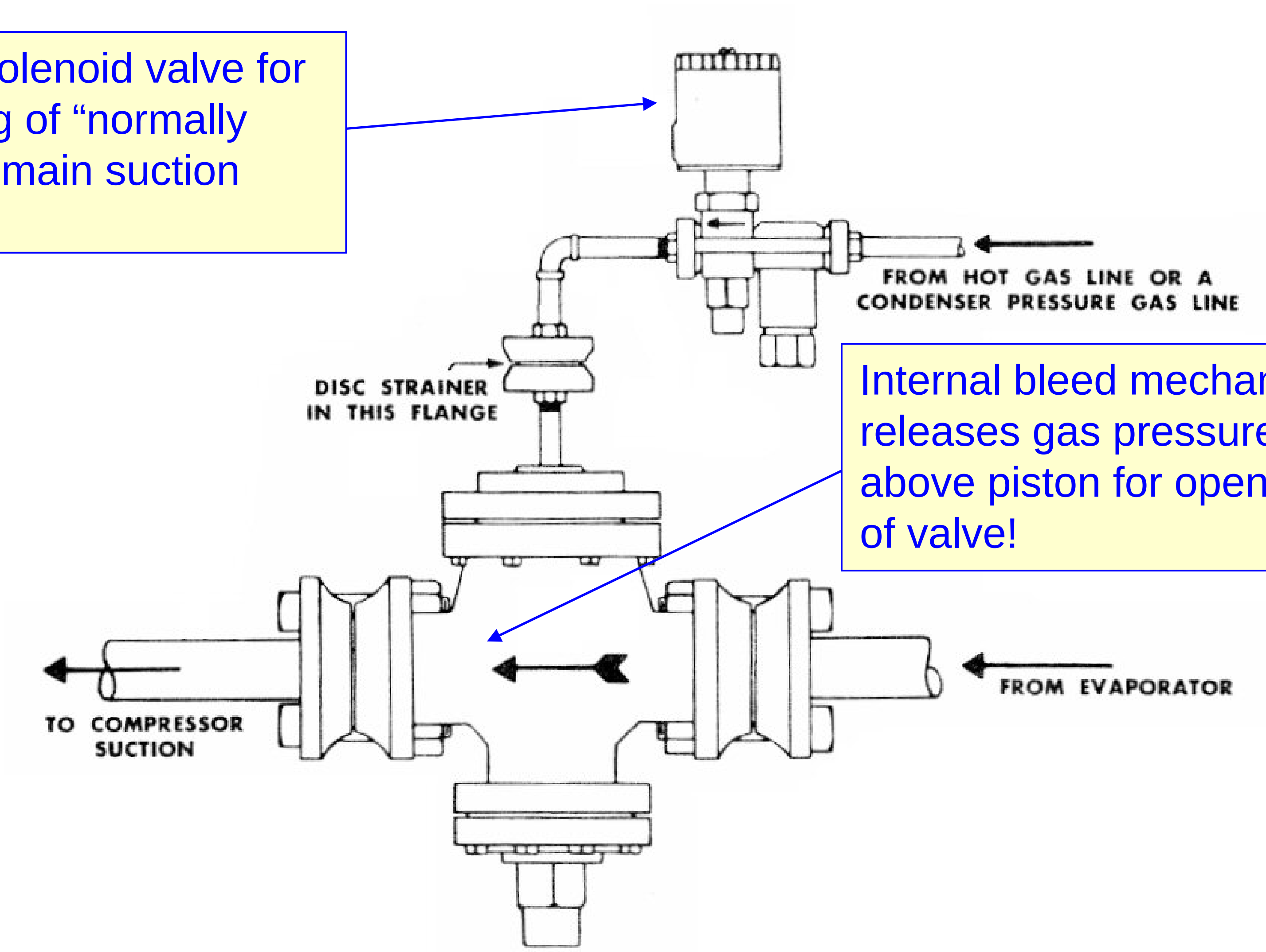


Fig. 4: Manuf. Recommended Valve Arrangement

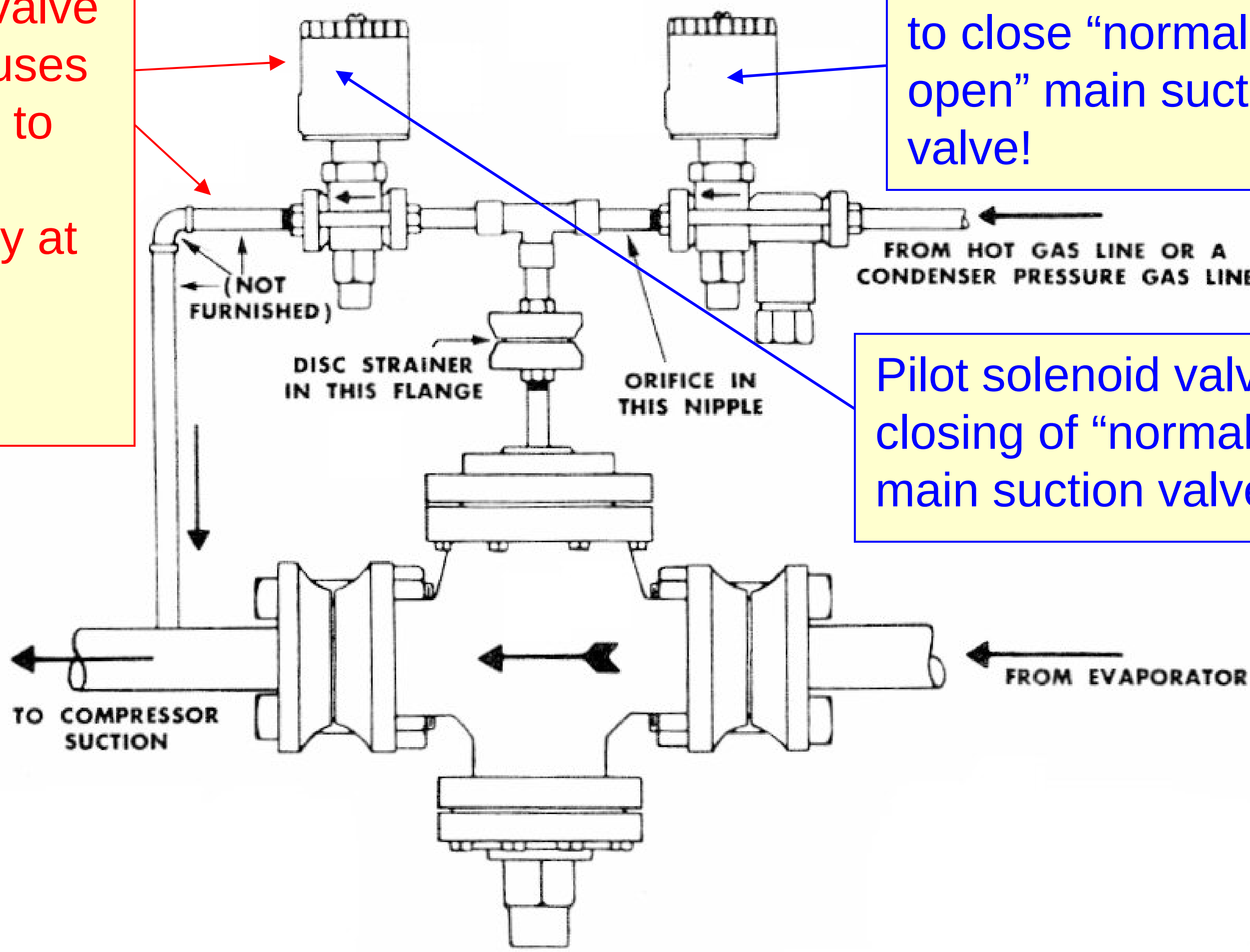
Pilot solenoid valve for closing of "normally open" main suction valve!



Internal bleed mechanism releases gas pressure above piston for opening of valve!

Fig. 5: Actual Valve Arrangement

This solenoid valve connection causes the main valve to open instantaneously at any upstream pressure!



Pilot solenoid valve to close "normally open" main suction valve!

Pilot solenoid valve for closing of "normally open" main suction valve!

Fig. 6: Actual Valve Arrangement

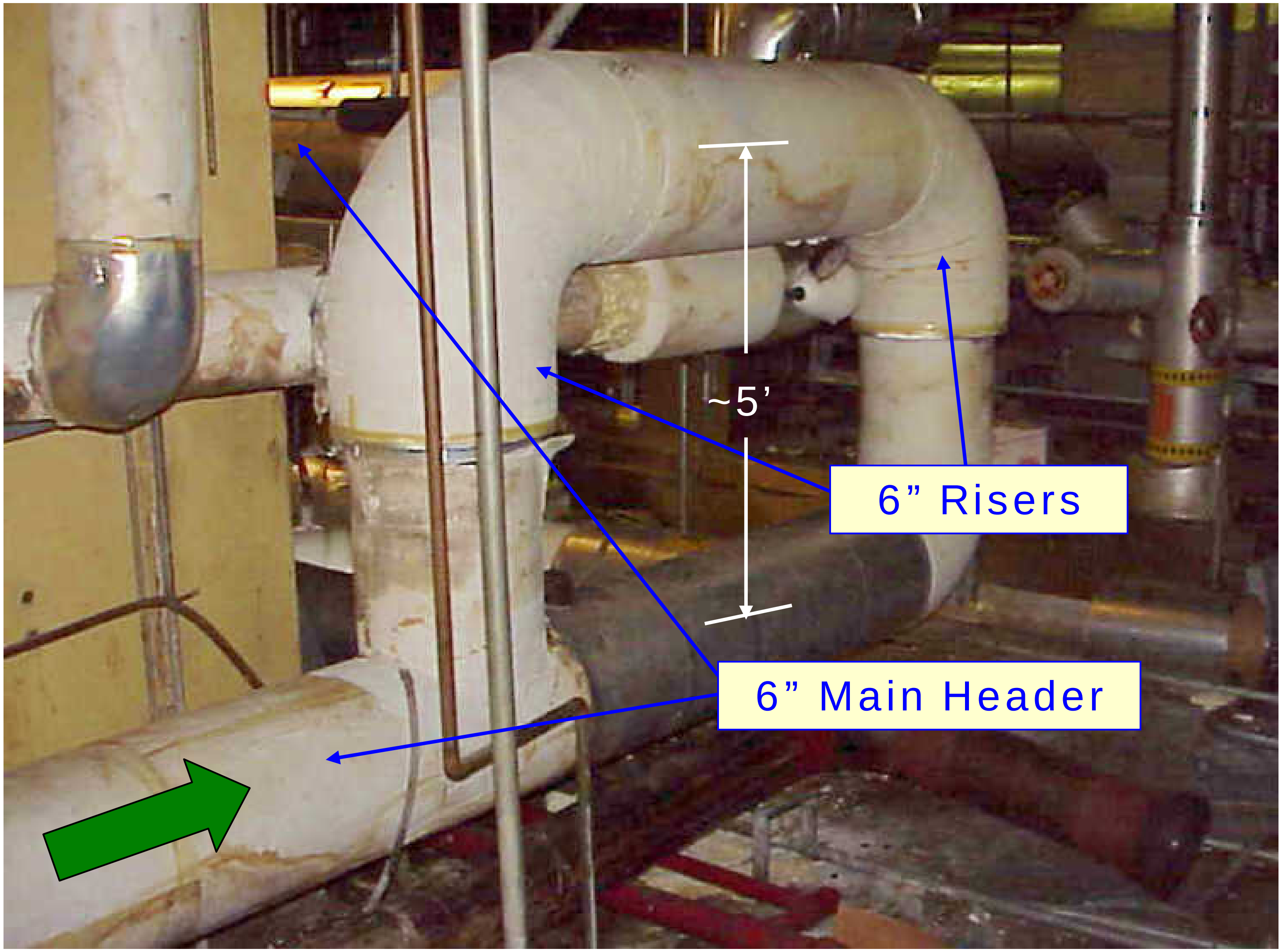


Fig. 7: Valve Group

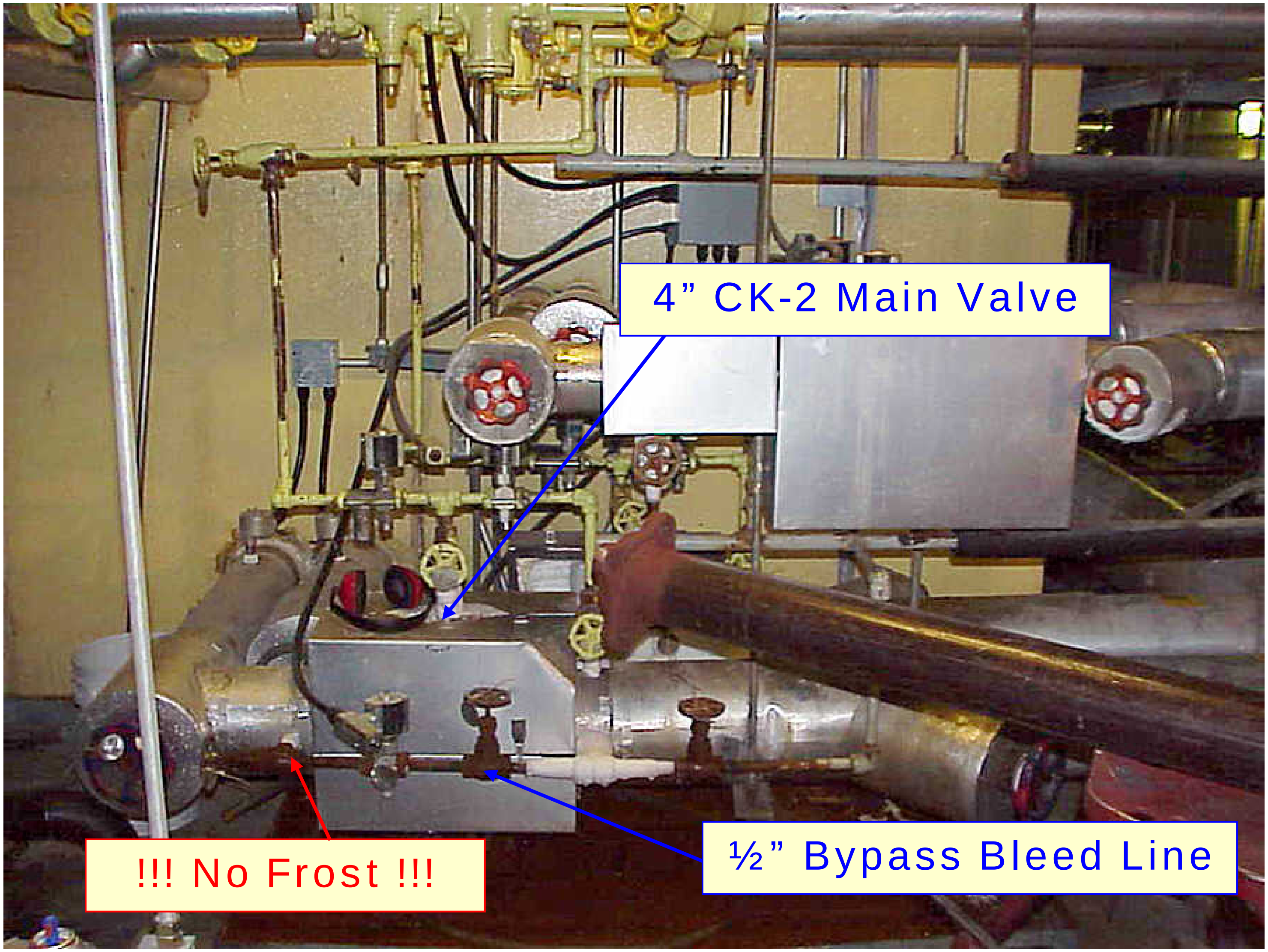


Fig. 8: Suspect Welding Practices

Movie Clip 1 & 2

Test simulating valve opening characteristics of CK-2 valve installed according to manufacturers recommendation:

Movie Clip 3 & 4

Test simulating valve opening characteristics of CK-2 valve not installed according to manufacturers recommendation.

Conclusions

Sufficient evidence indicates that the pipe rupture was caused by "hydraulic shock" induced by vapor propelled liquid. Contributing factors to this incident were multifold:

- The 6" main header created a liquid trap, i.e. during defrost mode this line holds a significant amount of liquid.

Conclusions (cont'd)

- The 4" main suction valve was not installed according to the manufacturer's recommendation, i.e. the built-in dampening feature of the CK-2 valve was bypassed with an external pilot solenoid valve. It is evident from the sequence of events and from observations that the ½" bypass bleed line malfunctioned, preventing the system pressure reducing from defrost pressure to a sufficient low pressure. This caused the main valve to open instantaneously at full back pressure causing the vapor to propel the liquid contained in the evaporator coil and piping system into the 6" main header. The "vapor propelled liquid" likely caused the "hydraulic shock". At this point it is difficult to say if the pipe rupture could have been prevented, if the CK-2 valve would have been installed according to the manufacturer's recommendation.

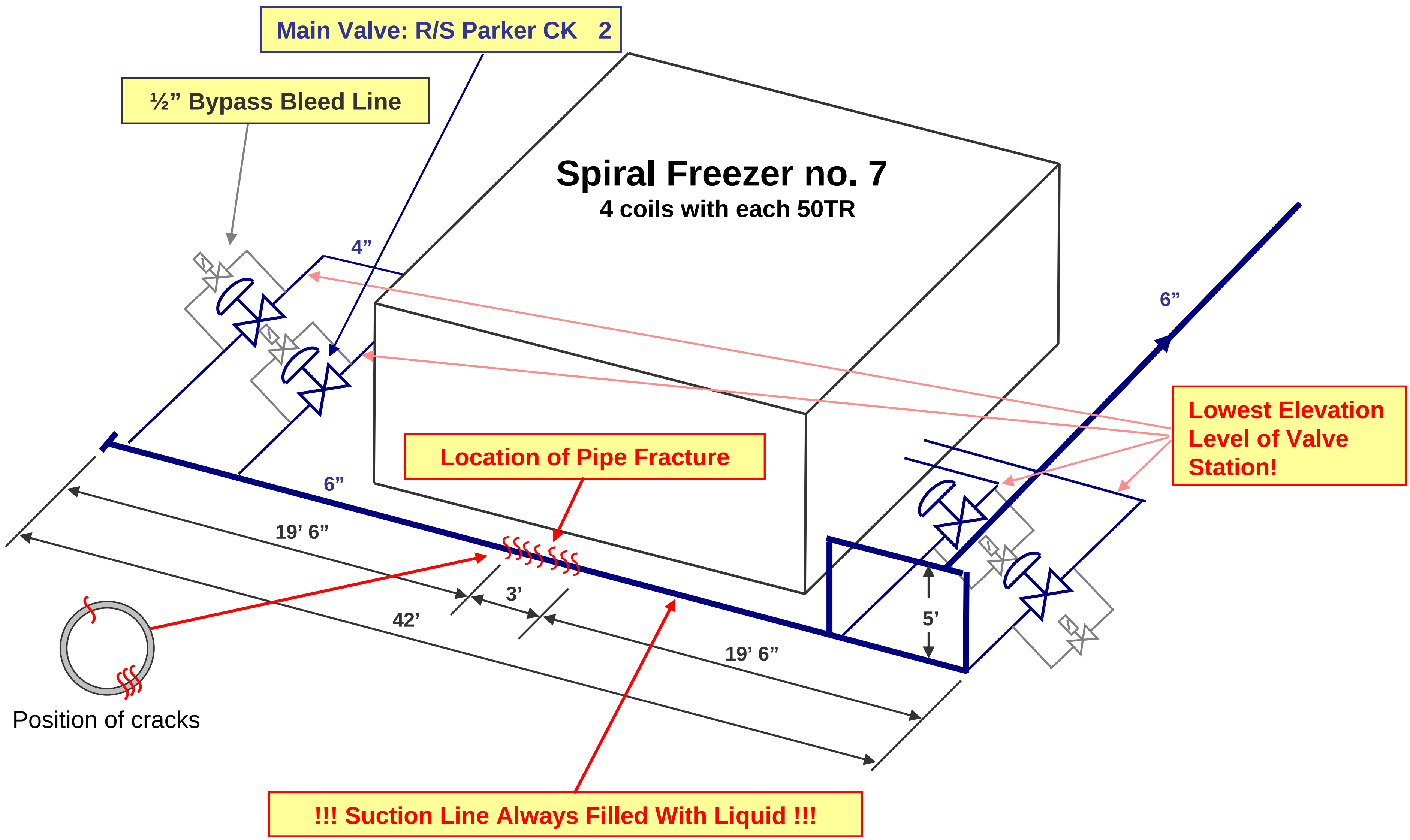
Conclusions (cont'd)

- The ½" bypass bleed lines of the outermost valve stations create a natural collection point for compressor oil and other matters. Excess accumulation of compressor oil in this line can create an oil blockage and/or cause the bypass solenoid valve to stick in the closed position. This would prevent the upstream pressure reducing from defrost pressure to system suction pressure.

Conclusions (cont'd)

- Stress crack corrosion was found to be present in the ruptured pipe section examined. Although the stress crack corrosion was not the leading cause for the rupture, it may have been a contributing factor and it explains why the cracks originated at the location where the pipe ruptured.

Figure 1: Schematic of Valve Group



Recommendations

1. Elevate the 6” main header by 5’ to the elevation of the connecting piping system. This will significantly reduce the likelihood of liquid trapping.
2. Replace the existing 4” CK-2 main suction with a CK-5 valve. This valve is a drop in replacement and will only open if the differential pressure is below 5 to 10 psi.
3. Relocate the ½” bypass bleed line such that any accumulation of compressor oil, dirt, debris, etc in the line is minimized.

Recommendations (cont'd)

4. Utilize the "condensate defrost line" in addition to the ½" bypass bleed line to reduce the pressure after the defrost cycle is terminated.
5. Inspect all pipes, valves and fittings that were subjected to the hydraulic shock for mechanical integrity.
6. Consider back welding screwed joints and replace pipes and fittings where nonstandard welding practices have been used. See Figure 8 and Figure 9 for reference.

Questions??

Comments??

Thanks!!!

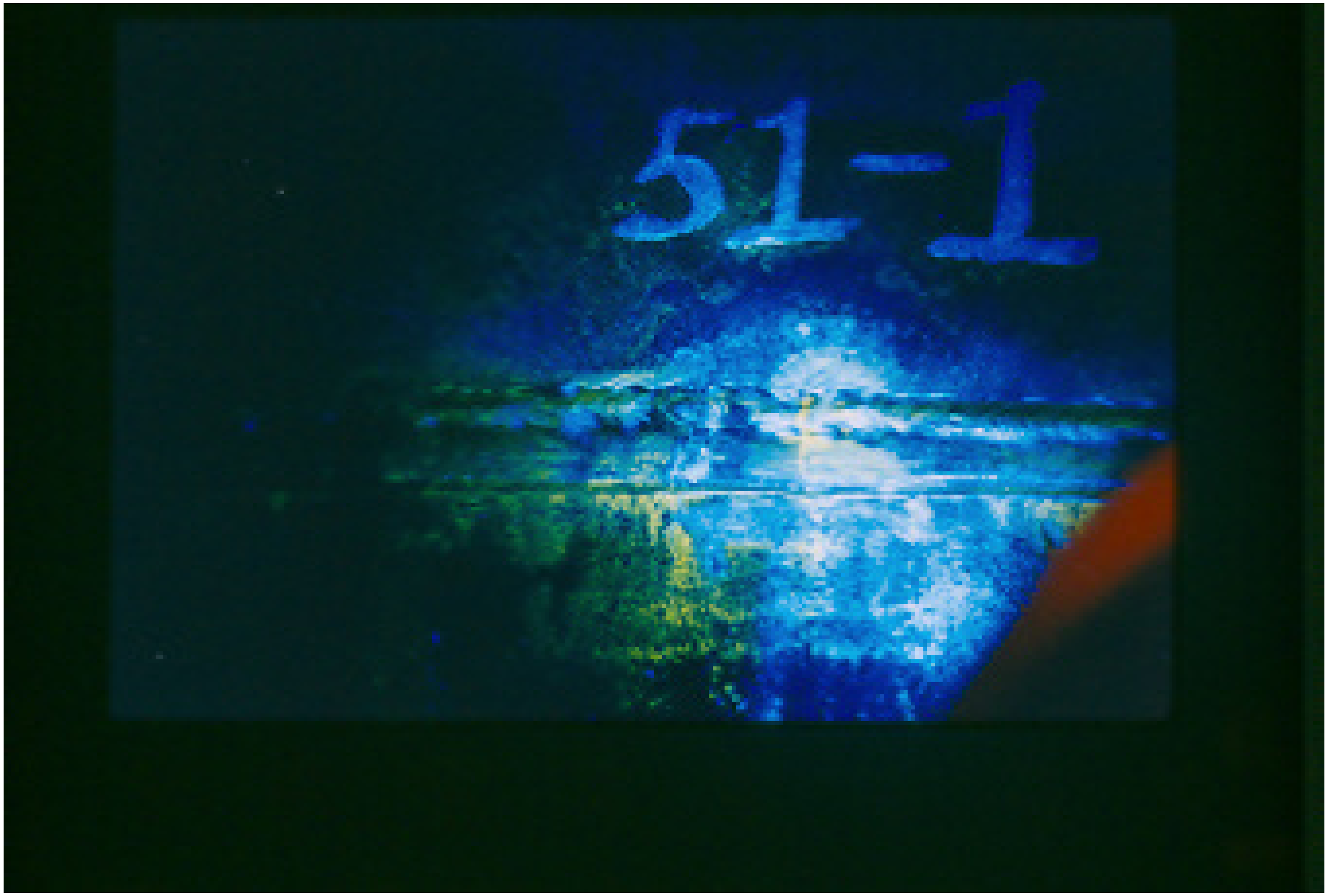
Tab 6

Mechanical Integrity Field Experiences

Dan Webb/Mike Carrell:
CF Industries

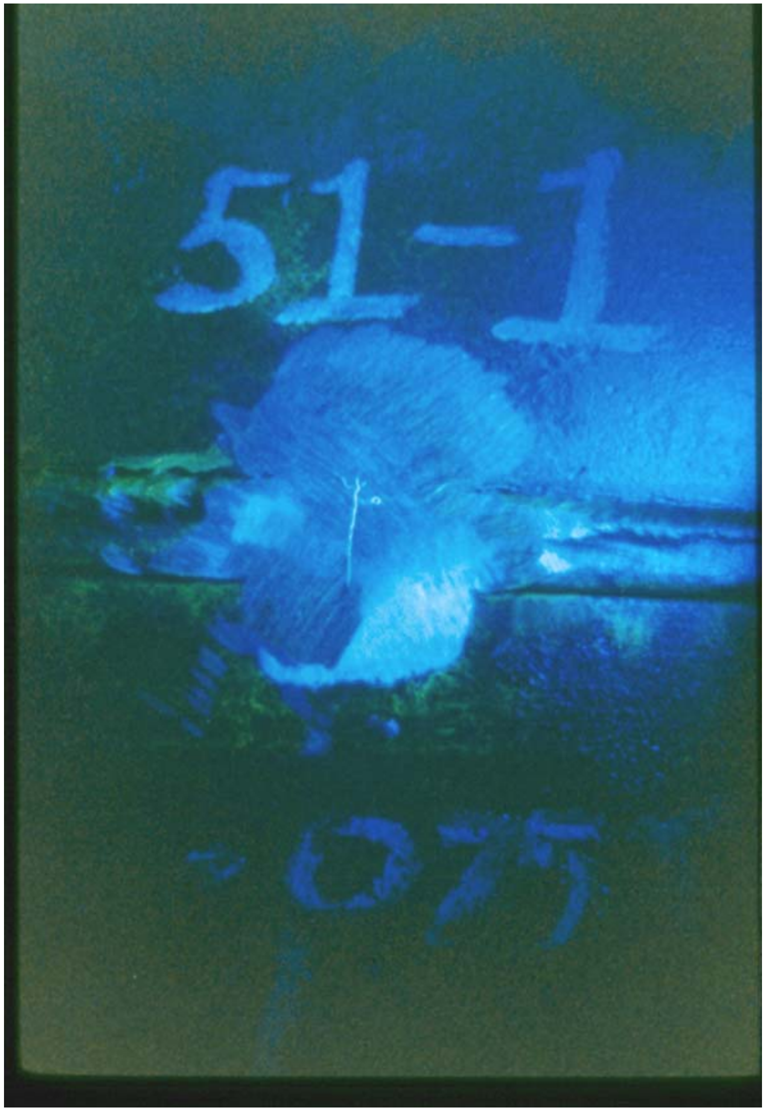
November 9 – 10, 2004
The Pyle Center, Madison, WI

Glenwood Terminal
LPST SCC Indication
Fluorescent Black Light View



Glenwood Terminal
LPST SCC Indication
White Light View

Glenwood Terminal
LPST SCC Indication
During Grinding Process



Glenwood Terminal
LPST SCC Indication
Surface Replica / Acid Etch

Glenwood Terminal
LPST SCC Indication
Total Removal

Glenwood Terminal
LPST SCC Indication
Weld Repair

IRC Mechanical Integrity Workshop

Presented by Dan Webb & Michael Carrell

CF Distribution Facilities Overview

CF Industries manufactures and distributes fertilizer throughout the United States.

The Anhydrous Ammonia and other nitrogen fertilizers are manufactured at two (2) facilities, one located in Medicine Hat, Alberta Canada and the other in Donaldsonville, Louisiana. CF also operates a phosphate mine in Hardee, FL and 2 phosphate manufacturing facilities, one in Bartow, FL and the other in Plant City, FL

The manufacturing facilities provide product to CF's Distribution Facilities. Finished fertilizer products are delivered to our distribution facilities by rail, barge and pipeline. As part of the distribution chain CF operates 23 distribution facilities throughout the upper Midwest of the US.

Dan Webb is the Manager, Engineering & Technical Services and I serve as the Superintendent, Mechanical Maintenance.

The following vessels and tanks compose the majority of what we are responsible for maintaining:

- 27 ea. - 15,000-30,000 Low Pressure Storage Tanks – Each tank is approximately 160 foot diameter x 75 foot tall.

- 50 ea. – pressure vessels – These pressure vessels operate between 30 psi up to approximately 250 psi.

- 28 ea. – ammonia heaters – These heaters are used to heat our ammonia from -28 deg F to approximately 40 deg F for shipment to our customers in tractor trailers. These heaters range in size from 9 to 29 MMBTU/hour.

- Over 100 Ammonia Compressors with individual cylinders ranging from 5” to 22.5” in diameter and connected horsepower between 25 and 350 each.

- Add to that the miles of piping that transports cold and warm vapor and liquid ammonia thru the system.

- These vessels and tanks are located in 8 states.

Each of these pieces of equipment has specific inspection and maintenance procedures that our operations, engineering and maintenance groups participate in. These procedures are detailed in CF’s Mechanical Integrity Procedure Manual

Mechanical Integrity Procedure Manual

Composed of 28 separate procedures that address the inspection and maintenance of

- Tanks and Pressure Vessels
- Piping and Fitting Inspections
- Control System Inspections
- Relief Valve and Vent System Inspections
- Emergency Shutdown System Inspections
- Pump Inspections
- Ammonia Condenser Inspections
- Ammonia Compressor Inspections
- Ammonia Heater Inspections

Inspection Procedures

Without going into detail on all our Mechanical Integrity Procedures I am going to take three (3) pieces of our equipment and discuss our inspection procedures and what we have adopted.

Low Pressure Storage Tanks

Our LPST inspection procedures have evolved since first becoming aware of SCC in the late 1980's.

Throughout our inspections we have purged our tanks with air and utilized water blast to remove all oil from the floor and shell (up to 10') until it was clean and dry. Parts of our discussions were around the use of a nitrogen purge. (Ammonia vapor to nitrogen purge to air)

Early in the process it was determined to perform our inspections at 15 year intervals. The driving purpose of our tank inspection program was safety. Since we could not verify the internal integrity of out tanks and vessels, the one method that provided us with the most comfort was an internal inspection. Secondly was the cost of the inspections, CF could justify performing between 2-3 inspections annually. This was based on having approximately 35 LPST in the system in 1985.

Dry magnetic particle inspection using red powder was used on the first few storage tanks. Only the floor and the first course welds were inspected. This method was used on approximately 6 tanks before going to the current process. This method met with limited success. Dry visible magnetic particle performed on an as welded surface, even with wire brushed does not provide sufficient contrast to discover the type indications which represent initial stages of SCC

To provide a more comprehensive examination the following criteria was established.

- Purge the tank with air.

- Clean the tank floor and 10 foot up the shell with hydro blast/solvent cleaning until floor and shell are clean and dry.
- Power wire brush all welds to be inspected.
- Vacuum Box inspection of all floor and corner welds.
- Wet-fluorescent magnetic particle (WFMT) inspection of all floor, shell, nozzle and attachment welds.
- Representative ultrasonic thickness on test on all floor plates and 4 vertical runs up the shell.
- An Internal and External API 653 inspection on the tank.
- WFMT on two random hold down straps.

We have now been in all our tanks once and we are preparing to begin the “second round” of inspections. This will be one indicator of whether there is a need for a nitrogen purge.

The result of this comprehensive examination is the discovery of anywhere from 100 indications to 450 indications in each tank. All indications were removed by grinding. Those that violated minimum wall requirements were weld repaired.

Note: During our inspections time was of the essence, therefore evaluation of the indications to determine cause was only performed on the early tanks in the process. For purposes of discussion I feel that the vast majority of the indications were manufacturing defects. There were a noticeable number that did exhibit the characteristics of SCC. The following slides show the discovery, evaluation, removal and weld repair of 4 such indications at our Glenwood, MN facility.

Once we determined that SCC was a significant concern on our tanks and vessels, we discontinued the process of determining cause of individual indications. Our focus was to return the vessels to acceptable operating condition. When a vessel exhibits unusual failure patterns then we will perform additional tests and inspections to determine cause and then provide corrective action to eliminate similar failures.

We have come to the conclusion that all tanks and vessels should receive an internal inspection AT LEAST once after construction and following a certain period of operation.

The necessity for a "baseline" inspection can be demonstrated by some examples of severe construction defects.

Examples of some of our more "dramatic indications.

- A transverse crack was found in an upper course of a tank. During grinding the indication shifted into a longitudinal indication and eventually into a lack of fusion line the exceeded 8 foot in length. This flaw was caused by an automatic welded that was not originally set up correctly and allowed to run during original construction.

- On the first course an area 3" long was discovered. This area was ½ inch wide and gave the appearance of the weld being shattered like auto glass. It ground out at ½ inch deep. It was determined that the nose of the automatic welder had disintegrated into the weld and deposited tungsten into the weld.

Pressure Vessels

Our pressure vessels should be separated into two categories; Bullets and Flash Tanks & Receivers.

Bullets

Our Bullets (warm product storage) operate at ambient temperatures and at a pressure of up to 250 psi. The inspection program on them has been consistent through the last 15 years.

We have completed two internal inspection cycles on all our bullets and are progressing through our third cycle now. The first two cycles were on a 5 year interval. These provided a good baseline and trend for our bullets. The internal inspection consisted of the following:

- Purge with air.
- Hydro Blast/Solvent cleaning until clean and dry.
- Power wire brush all internal welds.
- WFMT inspection of all internal welds

The third cycle has adopted the Risk Based Inspection (RBI) protocol into our system.

Let me give you a synopsis of our current bullet inspection program.
A bullet can be submitted for an RBI that has been shot peened and has had two internal inspections since shot peening without a “significant” indication. An RBI can extend the interval between internal inspection if the probability of failure and the consequence of that failure justify the extension. **We believe and it is generally accepted that at least one internal inspection is required to meet the requirements for extending the internal inspection interval.**

With each successive inspection the number and severity of the indications greatly reduced. Occasionally we did have a weld repair on second inspections. Some can be attributed to original construction (such as weld slag working its way to the surface) others again give the appearance of SCC.

We have one vessel in our system that is in opposition to the norm. The Garner, IA Bullet is 144” diameter x 112’ O.A.L. It can store 29,846 gallons of warm anhydrous ammonia. As with all our other bullets, we started the inspection process by shot peening the heat affected zones of the vessel interior following the first inspection.

With each successive inspection the number and severity of the indications has dramatically increased.

1992	6 indications	3 weld repairs
1997	21 indications	6 weld repairs
2002	102 indications	7 weld repairs

This next year we are going to look again at this vessel and bring in metallurgical engineers to evaluate the findings in an attempt to determine cause.

Flash Tanks & Receivers

These are operational vessels that are integral parts of our refrigeration system.

Originally they were put on an inspection schedule to match the LPSTs (every 15 years). Within the last 2 years, we have moved to a 10 year inspection frequency.

These vessels received the same type of inspection that the Bullets received.

- Purge with air.
- Hydro Blast/Solvent cleaning until clean and dry.
- Power wire brush all internal welds.
- WFMT inspection of all internal welds

There have been very few indication associated with these vessels and are currently be adopted into the RBI program. As with our other vessels, early evaluation of the indications revealed that SCC was present in our Flash Tanks and Receivers. CF then proceeded to remove and repair all future indications without performing evaluation on specific indications

Piping Systems

All our piping systems are inspected based on the requirements of API 570. The frequency of our piping system inspections is a three step program.

- Annual Inspection – this is performed by our operators and consists of a visual inspection looking for any deviations from normal operating conditions.
- 5-Year Inspection – This is performed by a certified API 570 inspector. This inspection is looking for many of the same deviations that are performed during the annual inspector. It includes the checking of hangers, supports, coating systems, insulation condition and any condition that might cause undue stresses on the piping system.
- 15-Year Inspection – It takes a 5-year inspection and thickness checks of the piping at suspect locations.

In almost all cases the replacement of piping was the result of external corrosion caused by coating failure. We have on rare occasion had a pinhole leak form which caused replacement of a section of a line. We have yet to perform an evaluation of any piping indications or pinhole leaks to determine cause.

Conclusion

SCC is a significant concern in Anhydrous Ammonia service. Although we do not have first-hand knowledge of a vessel rupture for which the root cause was SCC, there is a wealth of literature indicating the possibility of SCC occurring in carbon steel vessels, especially at elevated temperature and pressure. CF has thought it wise to perform our inspections and specify vessel fabrication materials and techniques with an eye toward minimizing the effects from defects including SCC.

Tab 7

Data Requirements for Best Practices (Breakout Groups)

November 9 – 10, 2004
The Pyle Center, Madison, WI

Mechanical Integrity Workshop

Second Breakout, Group 1 Worksheet

The focus of this breakout group is to develop priorities for mechanical integrity inspections.

To aid in the efforts of the group, we will develop a matrix showing the group's average opinion of the probability that a component will be involved in an incident/release and the significance of damage the group feels would be caused by that incident/release.

Below are a number of components identified by the First Breakout Groups as important for mechanical integrity inspections. Please rank each component's **Probability** of failure and **Impact** of failure on the following scale.

Rank from 0=**No** Probability/Significance to 3=**High** Probability/Significance

Component	**Probability of Failure**	**Significance of Failure**
*Component identified in first workshop*__________		
*Component identified in first workshop*__________		
*Component identified in first workshop*__________		
*Component identified in first workshop*__________		
*Component identified in first workshop*__________		
*Component identified in first workshop*__________		
*Component identified in first workshop*__________		
*Component identified in first workshop*__________		
*Component identified in first workshop*__________		
*Component identified in first workshop*__________		

Rank from 0=**No** Probability/Significance to 3=**High** Probability/Significance

Component	**Probability of Failure**	**Significance of Failure**
Vessels		
High pressure		
Medium pressure		
Low pressure		
Transfer vessels		
Vessel connections		
Oil pots		
Other: _______________		
Other: _______________		
Piping		
High pressure liquid lines		
Hot gas supply lines		
Ammonia condensate return lines		
Wet suction return lines		
Transfer system piping		
Thermosiphon piping		
Welds on any piping		
Insulation system jacket		
Insulation system vapor retarder		
Other: _______________		

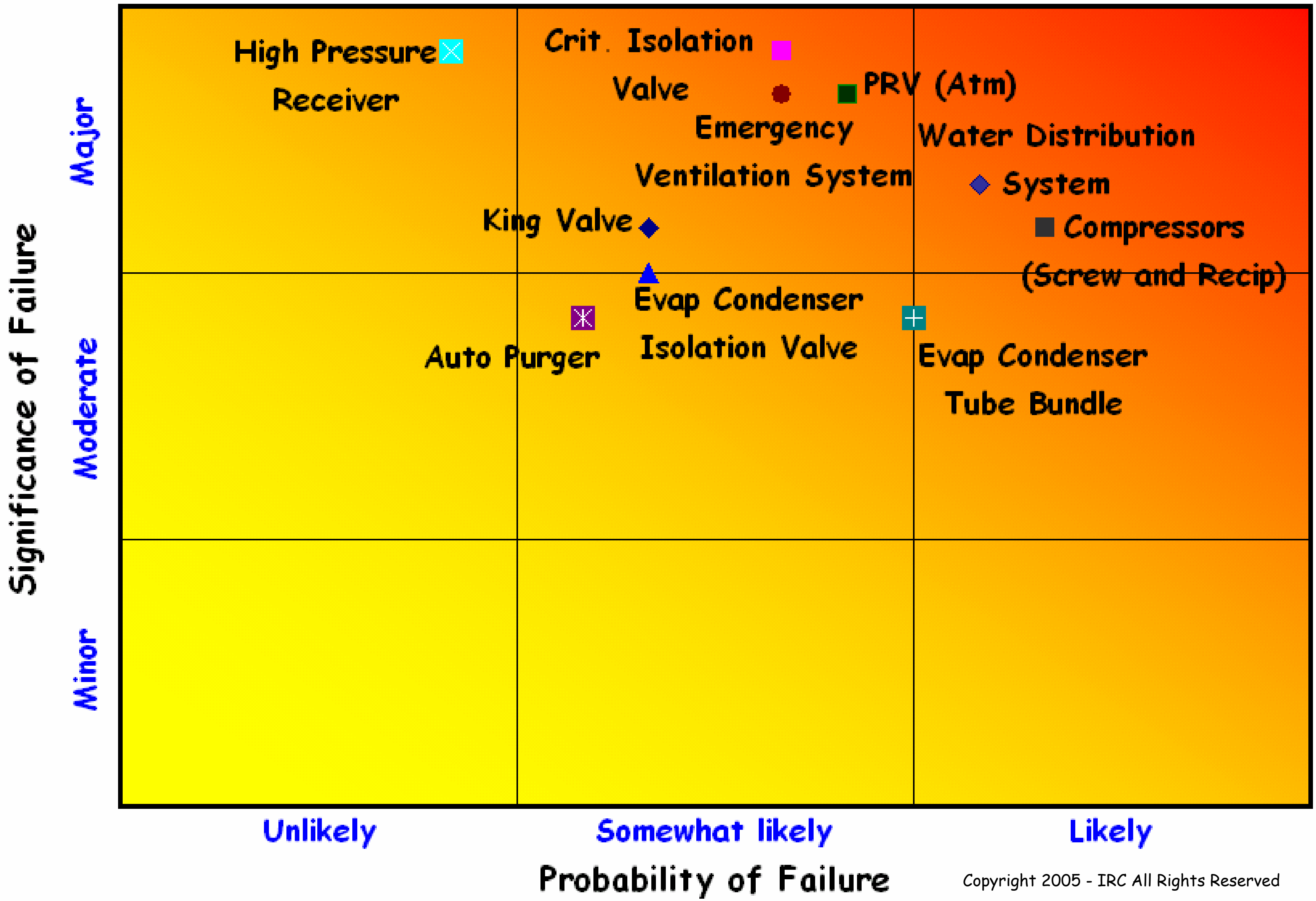
Rank from 0=**No** Probability/Significance to 3=**High** Probability/Significance

Component	**Probability of Failure**	**Significance of Failure**
Valves		
King valve		
Critical isolation valves (manual)		
Critical isolation valves (automatic)		
Pressure relief valves (atmospheric)		
Pressure relief valves (internal to system)		
Valve that does not properly hold		
Other: ________________		
Other: ________________		
Heat Exchangers		
Evaporator tubing		
Evaporator headers		
Condenser, evaporative heat exchanger		
Chillers		
Jacketed vessels (silos, tanks)		
Other: ________________		
Other: ________________		
Other: ________________		

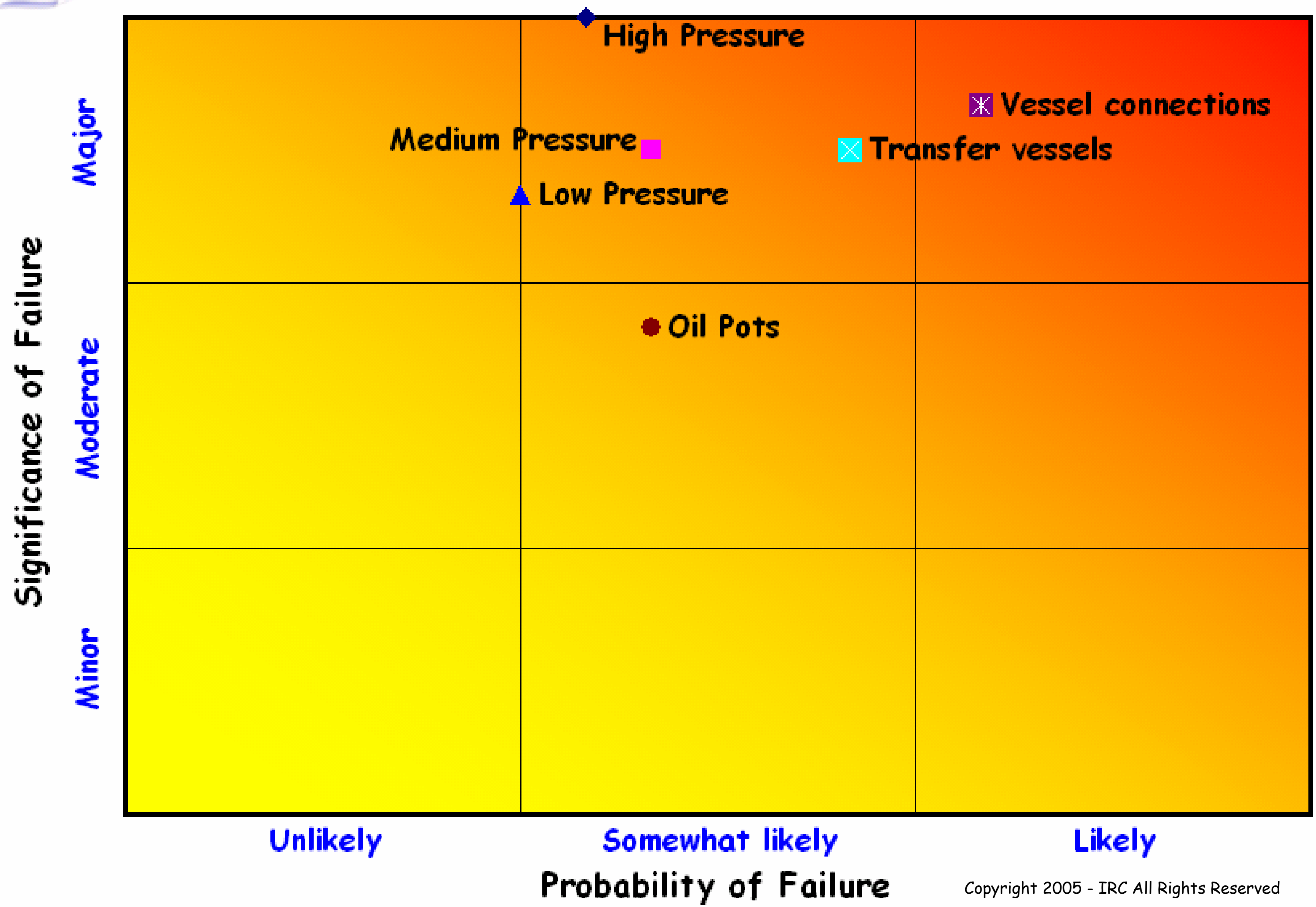
Results of Second Breakout Group 1

IRC Mechanical Integrity Workshop November 9-10, 2004

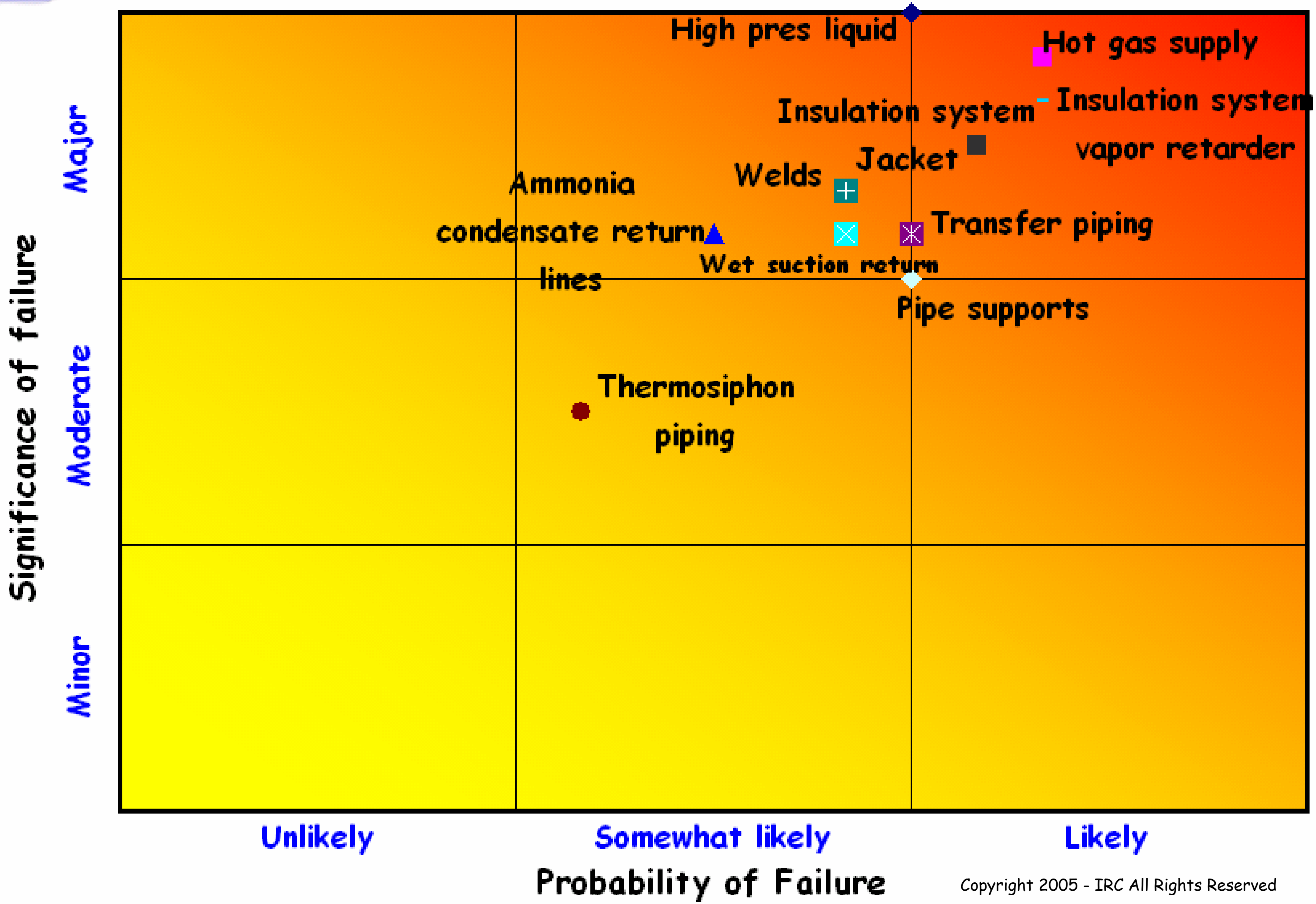
IRC Mechanical Integrity Workshop - Highest Priority



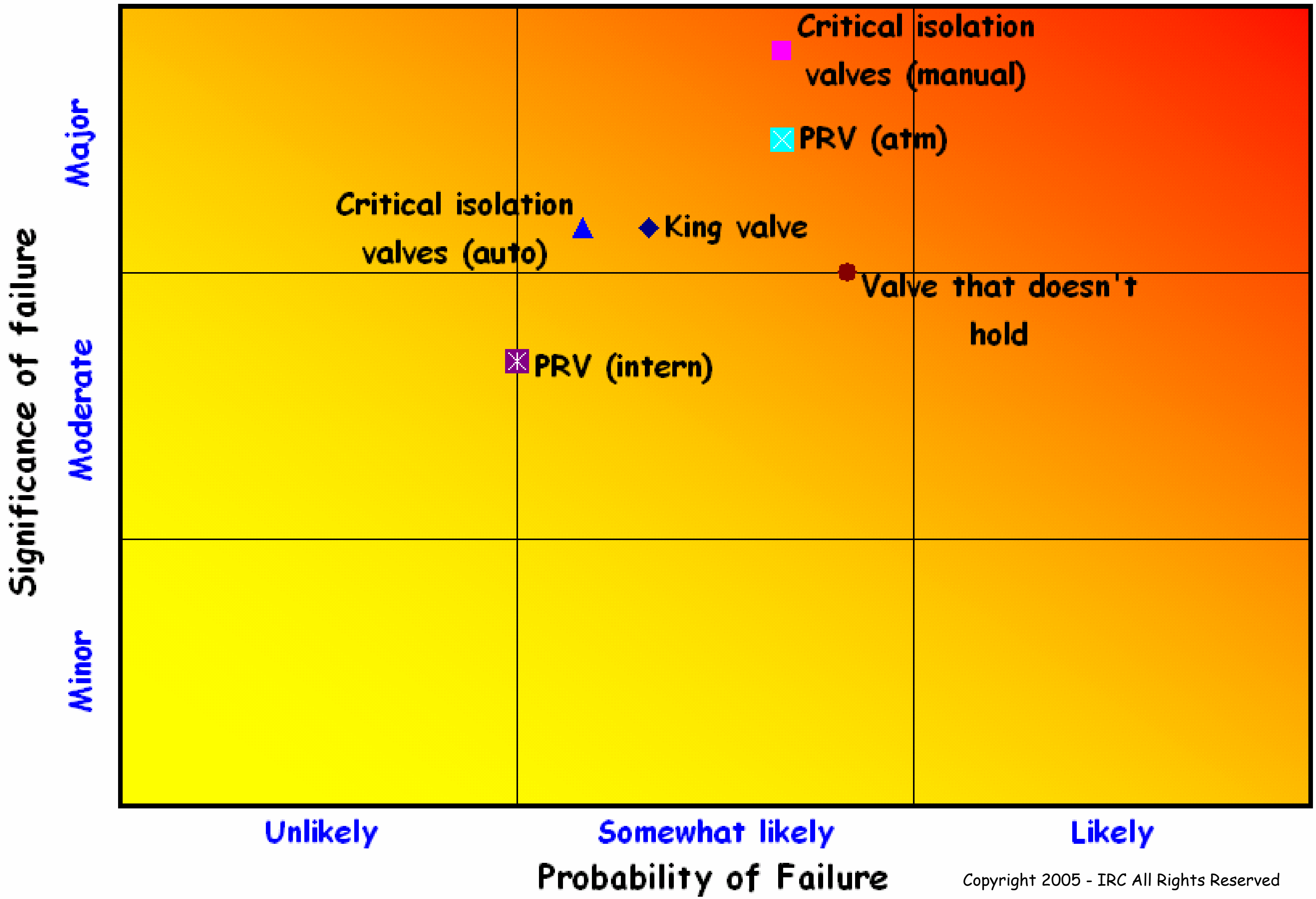
IRC Mechanical Integrity Workshop - Vessels



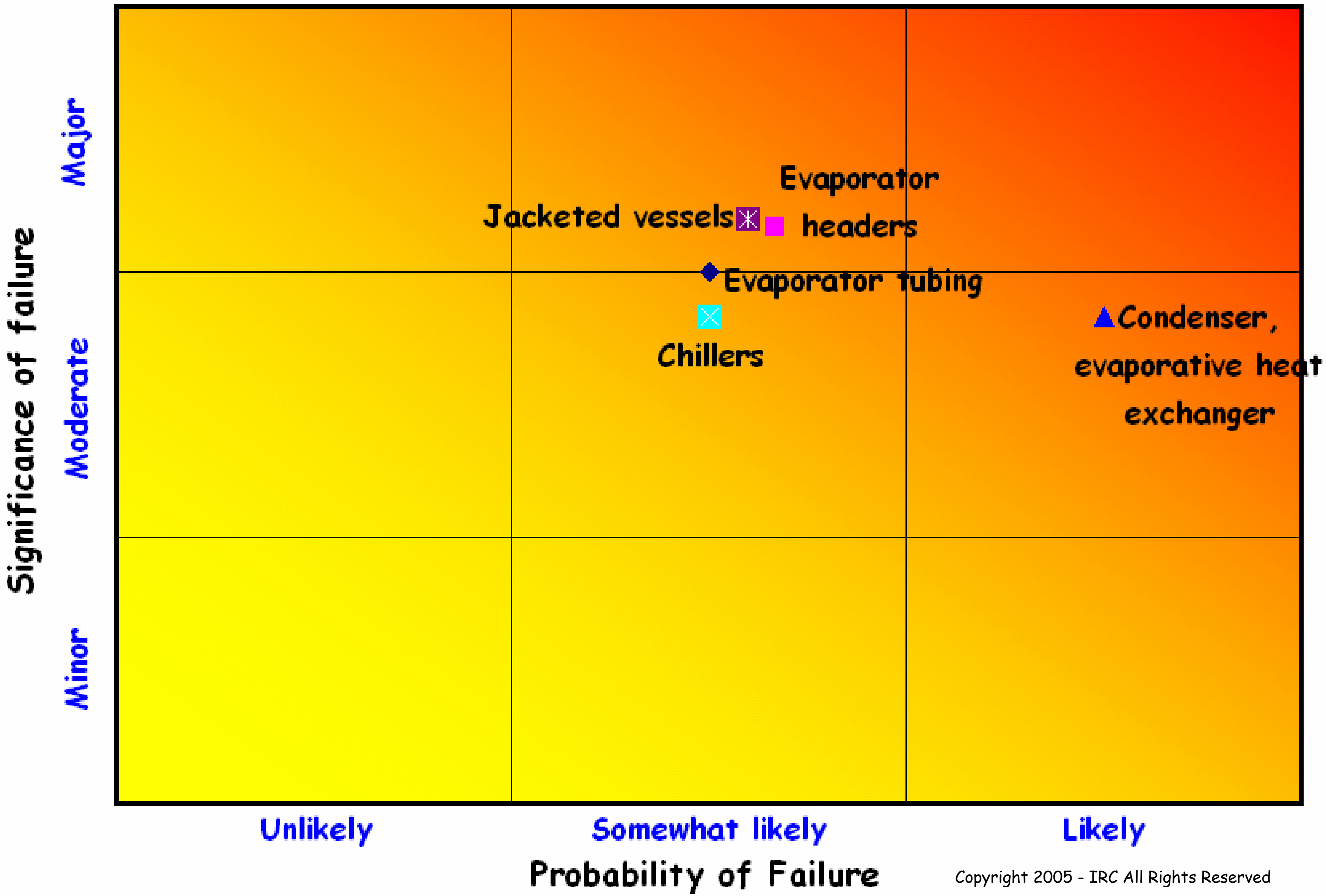
IRC Mechanical Integrity Workshop - Piping



IRC Mechanical Integrity Workshop - Valves



IRC Mechanical Integrity Workshop - Heat Exchangers



Mechanical Integrity Workshop

Second Breakout, Group 2 Worksheet

In this breakout group, we will consider the needs of a proper mechanical integrity program. We will discuss the resources available and the resources needed, specifically:

- **What resources, information, data, guidance, technology, outside support, etc. are required to support effective MI programs in this industry?**

List your resource ideas here:

Item	Resource Need	Exist? (circle)	If yes, where?
1		Yes/No/Unknown	
2		Yes/No/Unknown	
3		Yes/No/Unknown	
4		Yes/No/Unknown	
5		Yes/No/Unknown	
6		Yes/No/Unknown	

7	**Yes/No/Unknown**
8	**Yes/No/Unknown**
9	**Yes/No/Unknown**
10	**Yes/No/Unknown**
11	**Yes/No/Unknown**
12	**Yes/No/Unknown**
13	**Yes/No/Unknown**
14	**Yes/No/Unknown**
15	**Yes/No/Unknown**
16	**Yes/No/Unknown**
17	**Yes/No/Unknown**
18	**Yes/No/Unknown**
19	**Yes/No/Unknown**
20	**Yes/No/Unknown**

Results of Second Breakout Group 2

IRC Mechanical Integrity Workshop November 9-10, 2004

What resources, information, data, guidance, technology, outside support, etc. are required to support effective MI programs in this industry?

****Note: some of these exist and are essential, others are a "wish list".**

Resource Need	Exist	If yes, where?	# of Votes
Model for developing an economic justification for MI at each plant/Risk Based Insp.	No		13
MI inspection plan (plant specific)	Unknown		9
Buy-in from upper management to do MI	Unknown		7
MI audit database/checklist (similar to Nestle's)	No		6
MI trained people (plant and corporate)	Unknown		6
Insulation standard/guideline for the industry	No		4
Compliance with bulletin 109 & 110	Yes	IIAR	4
Method to qualify contractors (NDE, insulation, piping, construction, electrical/controls)	No?	Some certifications exist	3
"Certified" inspectors (inspectors from regulatory agencies trained in ammonia ref.)	No		3
List of typical failure methods for ammonia refrigeration	No	Not publicaly, at least	2
Failure history (plant/corporate specific)	Unknown		1
Cost effective (cheap) testing methods/technology	Unknown		1
Method/technology for detecting moisture in insulation	Yes	Thermograhy, moisture probes, etc.	1
Rating system for insulation/vapor retarded effectiveness	No		1
Help for "Mom & Pop" plants	Yes	IIAR new PSM package	0
Installation standard for refrigeration systems	Yes & No	No single document	0
Matrix of NDT test methods for various components	No		0
Website listing "MI Best Practices"	No		0
NDT Ultrasound measurement techniques	Yes	Industry	0
Method/technology for inspection without insulation removal	Yes	Thermograhy, Lixi, etc.	0
Method/technology for external SCC detection	Yes	UT, Acoustic Emmission	0
Database of NDE contractors knowledgeable in ammonia refrigeration	No		0

What resources, information, data, guidance, technology, outside support, etc. are required to support effective MI programs in this industry?

Second List Proposed by a Group Member
1.) Failure mechanics
2.) Determine method of discovery
3.) Develop MI procedure
4.) Effective implementation
5.) Documentation

Mechanical Integrity Workshop

Second Breakout, Group 3 Worksheet

Our task in this breakout group is to consider principles associated with "**designing for mechanical integrity**." We will discuss what designers, contractors and owners can do to make industrial refrigeration systems more effective in the area of mechanical integrity.

- **What can designers (and manufacturers) do to improve the mechanical integrity of industrial refrigeration systems?** As you list your ideas, consider the following areas: materials of construction, equipment arrangements, accessibility for inspection and testing, coatings/paint, active or passive systems (for corrosion control), dynamic on-line monitoring, etc.

List your "design for MI" ideas here:

1

2

3

4

5

6

7

8

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11

12

- **What can contractors (refrigeration and NDT) do to improve the mechanical integrity of industrial refrigeration systems?**

List your ideas for how contractors can improve MI here:

1

2

3

4

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11

12

- **What can owners/operators do to improve the mechanical integrity of industrial refrigeration systems?**

List your ideas for owners to improve MI here:

1

2

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11

12

Results of Second Breakout Group 3

IRC Mechanical Integrity Workshop November 9-10, 2004

What can designers (and manufacturers) do to improve the mechanical integrity of industrial refrigeration systems?

Automated MI (moisture sensing, AE, vibration, H2O treatment...)
Low tensile steel for vessels (55 class)
Stress relieving of valves/vessels
Industry wide specs to include: insulation, vapor stops insulation, welding, pipe hanger/supports, corrosion allowance
Pre-insulated pipe
Corrosion protection
Pipe hanger/supports
30" Insulation wrap (vapor barrier)
Training/experience for designers
PHA
Pipe spacing to allow access for inspection
Dry air purge of relief valve vent lines
No trapped liquid between valves & suction lines
TML's (thickness measurement locations) and other reference points for testing
"Rhino liner" coating
Valve groups on roof
Extra space for lift maneuvering
Impact protection
Stainless steel for valves, piping, evaporators, pressure relief valves, etc.
Man ways in vessels for inspection purposes
Extra heavy pipe for small diameter pipe (schedule 120)
Vessels with large charge only located in mechanical rooms
Minimize roof/wall penetrations
Minimize threaded fittings
Stem caps in lieu of hand wheels

What can contractors (refrigeration and NDT) do to improve the mechanical integrity of industrial refrigeration systems?

NDE procedures in-place up-front
Contractor qualification (experienced in ammonia)
Contractor validation (managing all crews)
Owner-representative => site management
Quality control methods (insulation)
Material quality control (materials, piping, mill specs)
Certified welders
Weld procedure test practices (no backing rings, tig vs. stick)
Training (insulator certification construction management)
Hanger detail/installation
Penetration details
Partnerships

What can owners/operators do to improve the mechanical integrity of industrial refrigeration systems?

Documentation (complete & delivered)
Performance guarantee
Verification of materials
Design for inspection
Design for maintenance (not shipping)
Standards for maintenance
Equipment issue forum

Tab 8

Additional notes recorded during the workshop

November 9 – 10, 2004
The Pyle Center, Madison, WI

Tab1 - Welcome and Workshop Goals

Doug Reindl, IRC

- Review NDT technologies – methods, limitations, practices
- Review PSM requirements for NDT
- Exchange information between NDT contractors and end-users
- Identify best practices for conducting non-destructive evaluation for mechanical integrity

Additional Notes:

The following are attendee's responses to the question, "What would you like to take away from this workshop to make it a success for you?"

- NDT methods for in situ vessels
- What are the "hot regulatory issues?"
- Manufacturer feedback
- Guidance on standards required/suggested to use
- Ideas to improve our PM & MI programs
- Ideas to make our plant safer
- Advice for smaller plants
- Comparison of how our MI program "stacks up"
- Ideas on what does a "good" program look like
- Improving MI through NDT methods
- What's required for MI programs
- Make our ammonia system as safe as steam system
- On-line NDT methods
- New technologies, next generation NDT equipment
- Inspection intervals
- Early warning signs
- Best practices for MI to transfer to end-users
- What are appropriate codes, standards, guidelines for MI in ammonia refrigeration
- Cost-effective MI programs
- Effects of impurities on system (e.g. calcium chloride)
- Is air purging of vent piping effective?

Tab 2 - Overview of PSM Requirements for Mechanical Integrity

Doug Reindl, IRC

- Applicability
- Written procedures
- Components
  - Piping
  - Vessels
  - Insulation
- Training
- Inspection and Testing
  - Methods
  - Frequency
  - Documentation
  - Equipment deficiencies
- Quality Assurance
- Relationship to Process Safety Information

Additional comments from participants during presentation:

- Refrigerant contaminant
  - I saw internal corrosion from calcium chloride leaking into the ammonia system
  - Maybe we need to do an analysis of the ammonia for contaminants?
  - Look for secondary fluids leaking over to the ammonia
  - I have seen many incidents of facilities with severe air and water contamination in the ammonia, but this does not cause corrosion problems like the other secondary fluids.
- Using stainless steel for valve stems
  - A number of our plants automatically replace valves stems with stainless steel.
  - Some of the manufacturers use stainless steel for the spindles automatically
- Pressure Relief Valves (PRV)
  - I was told by an inspector that all PRV's should be tested to build a history regardless of whether they are to be trashed or rebuilt.
  - I've seen PRV's that were fully plugged
  - Though the 5 year changeout is not a "standard", this appears to be the standard cycle time of the industry
  - If you do not follow the generally accepted "industry standard", what you are doing should be at least as good or better.

- 5 year changeout is a guideline from IIAR but not a standard. OSHA just turned it into a "standard".
- But valve manufacturer's have also mandated 5 year replacement for their valves. [IIAR 109, 110 and Std. 2 all say to follow manufacturer's recommendations.]
- You may never know if the PRV popped without an ammonia sensor. But the sensors don't work without airflow. We blanket our sensors with a constant stream of -40F dewpoint dry air by pushing it through the pipe. This prevents rust from occurring in piping and PRV and can extend the time between changeouts.
- Ignoring the time period between changeouts, most vent piping I have seen doesn't even meet code as installed.

- Corrosion
  - You cannot use original vessel specs to get a corrosion rate because of discrepancies in the actual measurement versus average measurement for entire vessel.
  - If you see corrosion: clean, measure, repair and come back later to see if it is still corroding. That's all that matters.
  - You need to look to see if corrosion protection measures worked.
  - We look at more than single points. We want to look at many points to find the sensitive areas.
  - There should be no external corrosion on a properly insulated/protected system.
  - Determination of corrosion rate leads to a prediction of useful life.
  - If you say there is 10 years of useful life left, you don't come back in 9.9 years to look. You look sooner.
- Be certain your purchasing department is on board with your MI program. If they are buying potentially inferior parts from an unapproved supplier, require a Management of Change order to make sure the part is approved for use or discourage its purchase.

Tab 3 - Overview of Current MI Standards in Refrigeration and Kindred Industries

Daniel Dettmers, IRC

- API 510 and API 570
- ANSI/API RP 572-2001
- API RP 574
- API RP 575
- ANSI/API RP 576-2000
- ANSI/API RP 578-1999

- ANSI/ASME B31.3-2002
- ANSI/ASME B31.5-2001
- ASME Section V - Nondestructive Examination (2001 edition)
- ANSI K61.1-1999/CGA G-2.1-1999
- IIAR Bulletin 109 & 110
- NBBI 2001 National Board Inspection Code (ANSI/NB-23)

Additional comments from participants during presentation:

- Steel Structures Painting Council (SSPC) guidelines
  - SSPC has guidelines that define "mild" versus "harsh" corrosion
  - Some information will be distributed to participants.
- How do we know if a vapor barrier is failed
  - Real problem if below 32F.
  - Moisture measurement probes?
    - Problem is that you need to pierce the vapor barrier
  - Infrared may be better because there is no damage to vapor barrier
- Does compromised insulation require replacement?
  - Do we distinguish the difference between piping that cycles above and below 32F and piping that is constantly below 32F? Or do we treat all compromised insulation the same?
  - Witnessed -45F uninsulated vessel that was in excellent shape. Protected by ice build-up.
  - Don't forget structural concerns when there is a heavy ice build up on piping or vessels.
- Weld inspection
  - Make it clear to the contractor that you will be checking whether you intended to check or not.
  - Record who the welder is of every weld. Then you can spot check each welder's work.
- ASNT certification is required for certain types of inspection
- In the ASME BPV, sections V, VIII, IX are the most important. Rest is not relevant to our industry.
- CGA 61.1
  - We use 55 class steel to make sure it is under 70 ksi
- Application of API standards to the ammonia industry
  - We follow API, many jurisdictions require it.
  - API relief capacity (fully engulfed in flames) is a major difference between API and IIAR
  - OSHA does not require API for ammonia refrigeration systems.

Tab 4 - MI Focus Area Workshop

IRC staff facilitates – all participate

Attendees split into break-out groups to prioritize areas of focus for insuring the on-going integrity of ammonia refrigeration systems. Each group will develop a consensus list of priority areas to be shared with other attendees.

See attached notes for results.

Tab 5 - NDT Best Methods for Ammonia Refrigeration – Contractor's Perspective

Jim Kovarik, ConAm Inspections

- Selection of NDT Technologies
- Damage Mechanisms
- Equipment and methods
- Keys to achieving a successful MI program
- Why should you initiate an MI Program

Additional comments from participants during presentation:

- Digital ultrasonic thickness meter
    - Liquids don't affect meter
    - Point measurement
    - May have to grind a rough surface to get good contact
    - Not good for welds
    - Must remove insulation, sometimes paint or other surface coatings
    - Not best for pits, depends on size of pit and size of probe.
- GUL-Long Range UT
    - 10% -15% of cross sectional area of the pipe must be affected to be detected.
    - Mastic "deadens" the wave
    - Limit to 1 long-radius elbow
    - Insulation may lower distances that it can monitor for the same reason as mastic
    - Only for defects that are perpendicular to the beam
    - Collar is 2 to 8 inches, rigid. Above 8 inches, they have an inflatable collar.
- Lixi Profiler
    - It measures relative loss compared to surrounding pipe. Cannot measure absolute values. Does "see" through insulation.
- Acoustic Emission
    - Method of listening for cracks popping

- Must over pressurize the vessel
- For atmospheric tanks, can do the bottom part of vessel by using pressure exerted by the head of liquid above it.
  - Liquid must be above 50F to work
- For a 20' long by 4' diameter vessel, 10 – 12 probes required

- Radiography
  - Very long discussion/demonstration on the abilities of digital radiography

Tab 6 - Mechanical Integrity Field Experiences

- Godan Nambudiripad: General Mills

Additional comments from participants during presentation:
  - Anheuser Busch has allegedly compiled data on how much it costs the company every time they have an ammonia release. Both from fines and lost production.
  - Suggest creating an insulation certification and then sample the insulation job just like we sample the welders' job.
- Bent Wiencke: Nestlé
  - Discussed Nestlé's MI program
  - Displayed a software tool developed by Nestlé that helped organize an effective MI audit
  - Discussed an incident at Nestlé
- Dan Webb/Mike Carrell: CF Industries
  - Showed pictures of the results of NDT they performed internally to their vessels.
  - Use wet magnetic fluorescent particle testing
  - Find dozens of indications during first inspections of vessels
    - Many are believed to be there from manufacture
    - Some have been confirmed as SCC
    - All are repaired
  - Just stating 2nd round of testing on new storage tanks to see how many new indications appear
- Steve Thiery: General Mills

Tab 7 - Data Requirements for Best Practices (Breakout Groups)

IRC staff facilitates – all participate

See attached notes for results.

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