



# **“Guidelines and Application Procedures for API 578 Positive Material Identification (PMI)”**

**Presented on : March 6, 2012**

**Presented by : Don Mears-Oil & Gas Industry Consultant & Trainer**





## Presenter: Don Mears

- President of Analytical Training Consultants
- Oil & Gas Industry Consultant for Thermo Scientific Niton XRF Analyzers
- Author of API RP 578 2<sup>nd</sup> Edition PMI Certification Course
- Certified API Training Provider Certification TPCP# 0118
- 30+ Years in the Oil & Gas Industry
- API Member and Sub-Committee Member on API Inspection Summit 2011



*Niton XRF Analyzers*



**API/TPCP -0118**





# Presentation Outline:

- Introduction
- New Construction- QA/MVP Programs
- Existing Piping Systems ( Retro-Active PMI ) Programs
- PMI Field Testing Methods ( XRF or OES ) Technologies
- Control of Incoming Materials & Warehouse
- Elements of Maintenance Systems for PMI
- Recording & Reporting PMI Test Results
- Conclusion ( Questions & Answers )





## Introduction: “Why should you implement PMI according to API 578 ?”

- Note: The leading insurance industry statistics indicating that the US refining sector has more than three times the rate of property losses of refineries overseas.
- Dr. Moure-Eraso with USA Chemical Safety Board (CSB) urges companies to take action to prevent accidents, including:
  - Implement a robust **“mechanical integrity”** programs with an emphasis on thorough inspections of critical equipment
  - Monitor process safety performance using appropriate leading and lagging indicators to measure process safety **“before major accidents”** occur
  - Maintain an open and trusting safety culture where near-misses and loss of containment incidents are reported and investigated



Aerial view of the damaged heat exchangers following the April 2, 2010 fire



Close-up of ruptured heat exchanger



## Introduction: “Corrosion Failures in Process Piping”

- 41% of the largest losses in the hydrocarbon processing industry resulted from failures in piping systems<sup>①</sup>.
- Corrosion is one of the leading causes of piping failures.
- OSHA’s National Emphasis Program (NEP) includes positive material identification (PMI) as a part of Mechanical Integrity (MI)
- “Recognized And Generally Accepted Engineering Practices” or **“RAGAGEP”**
  - Example RAGAGEP for PMI:
    - API RP 578, Material Verification Program for New and Existing Alloy Piping Systems, Section 4.3
    - CSB, Safety Bulletin – Positive Material Verification: Prevent Errors During Alloy Steel Systems Maintenance, BP Texas City, TX Refinery Fire

① Second International Symposium on the Mechanical Integrity of Process Piping  
January 1996, Houston, TX, USA



## Introduction: Why Did OSHA Establish the “ National Emphasis Program” (NEP) Program in USA?

### Occupational Safety and Health Administration (OSHA) Acts

Process Safety Management (PSM) 1910-119-Highly Hazardous Chemicals (HHC) 2/24/1992 (Regulation)

Refinery National Emphasis Program (NEP) CPL 03-00-004 6/7/2007 (Enforcement)

Chemical National Emphasis Program (NEP) 09-06 (CPL 02) Notice – Pilot NEP 7/27/2009 (Enforcement)

### American Petroleum Institute (API)

Standard-API-570-Piping Inspection Code

Standard-API-510-Pressure Vessel Inspection Code

Standard-API-653-Storage Tank Inspection Code

Recommended Practice-API RP-578-Material Verification Program-MVP/PMI

Recommended Practice-API 571 – HF Corrosion in CS Pipes ( REs, Cr, Cu, Ni )

Recommended Practice-API 939-C-Guidelines for Avoiding Sulfidation, & Retro-Active PMI, 7.1.4&5

### Mechanical Integrity Needs in the Oil & Gas Industry

Understanding HOW, WHY, & APPLYING:

- ✓ API 578 PMI Guidelines and Applications
- ✓ Proper Training and Refresher Training Needed
- ✓ Data Management Software- Now Required for PMI (PCMS, Ultra-Pipe, Meridian, Solid PMI)



## New Construction: Do Not Rely Solely on Supplier “Material Test Reports” (MTR’S)

- Experience has shown that you cannot rely on material test reports (MTR’S) alone; there can be significant errors.
- One customer site survey revealed as much as 40% of material test reports (MTR’S) did not match actual chemistry. They also tend to loose the reports. They get separated from the existing material.

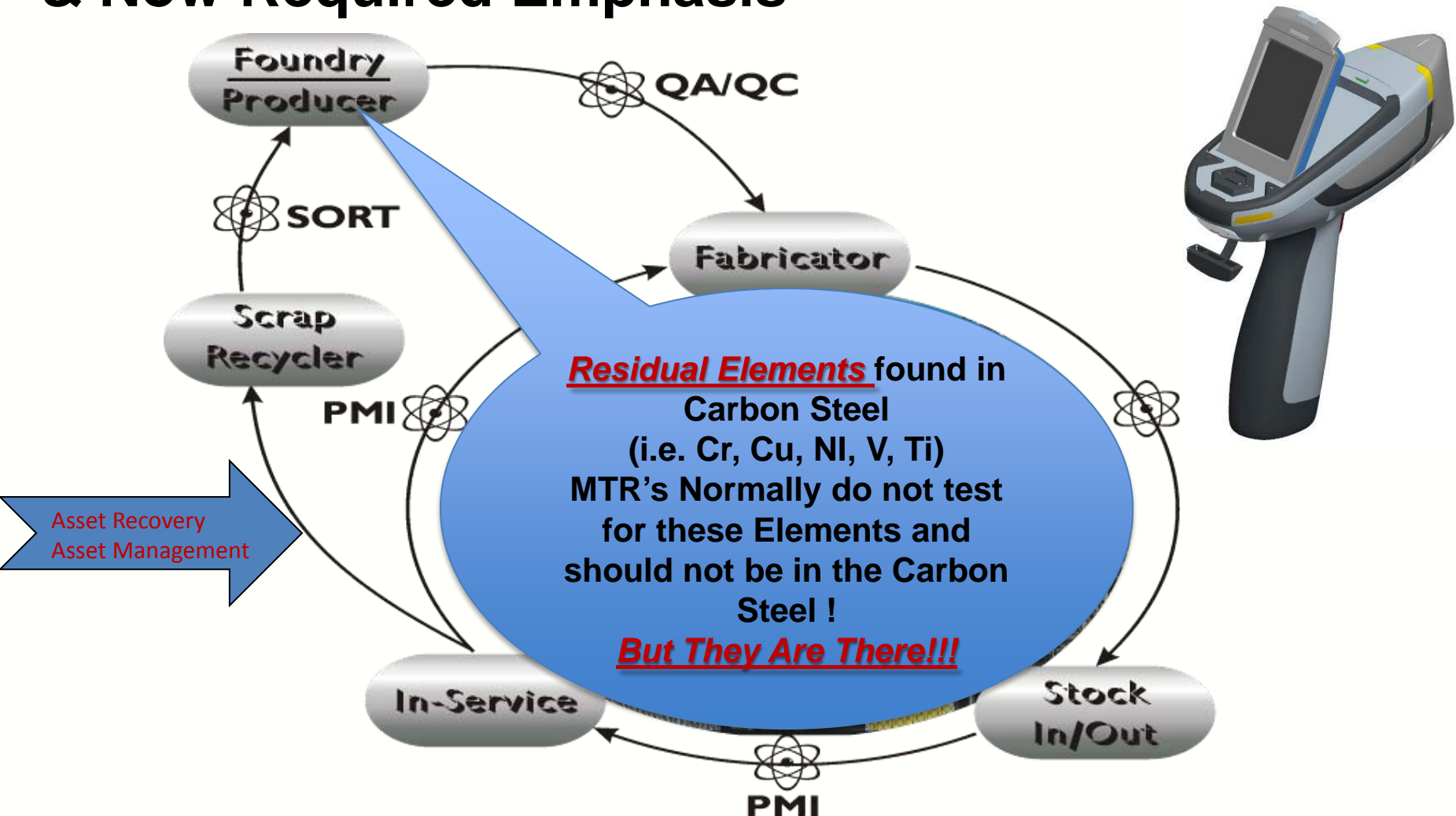
**“Trust but Verify” - This is what PMI is !!!**







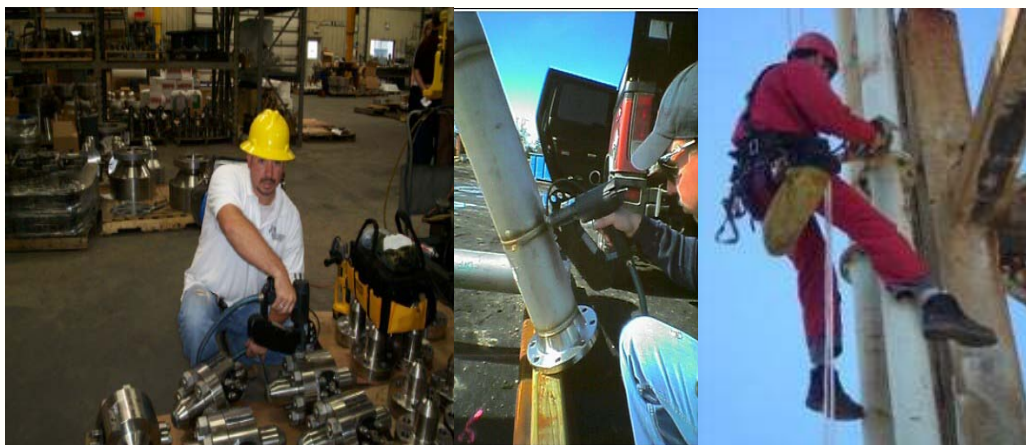
## New Construction: PMI Cycle Overview- Renewed & Now Required Emphasis







## New Construction- QA/MVP Programs



- New piping systems-Lay Down Yards
- Pipe fittings, valves & flanges
- Welds & welding consumables
- Longitudinal pipe and weld fittings
- Weld overlays or cladding



- Low Si in H & S Service
- Components from distributors
- Forgings
- Instruments
- Bolting
- Expansion joints and bellows
- HF Alky- Residual Elements



## Existing Piping Systems ( Retro-Active PMI ) Programs :

### Material Verification Program for Existing Piping Systems

- ❑ **Responsibilities** - The Owner/User is responsible for determining if a retroactive material verification program is appropriate for each existing piping system, for prioritizing the piping systems to receive retroactive PMI testing and for determining the extent of PMI testing required.
- ❑ **Prioritizing Piping Systems for Retroactive PMI Testing** - If Owner/User elects to prioritize piping systems for the material verification program or needs to determine whether PMI testing is needed at all, the Owner/User should consider the following:
  - ✓ **Likelihood of a material mix-up** during previous project and maintenance activities.
  - ✓ **Consequences of a failure.** Some factors to be considered include: flammability, fire potential, toxicity, proximity to other equipment or community, temperature, pressure, mode of failure, and size of release.
  - ✓ **Reason for alloy specification** (i.e., corrosion resistance or product purity).
  - ✓ **Historical data relating to inadvertent material substitution.** This may be related to previous experience with material nonconformities in the process unit or within the operating plant.



# **Existing Piping Systems ( Retro-Active PMI )**

## **Programs :**

➤ Material Verification Program for Existing Piping Systems  
Cont'd—Prioritizing Piping Systems for Retroactive PMI  
testing Cont'd :

- Carbon Steel Substitutions in Low Alloy Steel Systems
- Residual Elements in Carbon steels in HF alkylation Units
- Gasket Materials
- Process Units Susceptible to Sulfidation
- Construction and Maintenance Practices
- Reasons for the Alloy specification other than Corrosion or structural integrity—Example: SS for Lube Oil Systems used for oil Purity



# Existing Piping Systems ( Retro-Active PMI ) Programs :

- **Priority for API 578 2<sup>nd</sup> Edition:**
- **Residual Elements in Carbon Steels in Hydrofluoric Acid Alkylation**  
**Units:** Note: Carbon Steels in HF Acid service have been reported to suffer increased corrosion rates based on the Residual Elements (RE) in steels.
- In general, it has been reported to suffer enhanced corrosion impact of this in HF service.
- A guideline is that for base metal **0.15% wt % is optimum**. The concentrations to be measured in operations need to adopt.
- API RP 571—Pages 12,38

Ele	%	±2σ
LA-1215	0.0	
Iron/CS	0.0	
CuCrNi	0.132	
Mo	0.002	0.001
Nb	0.003	0.001
Cu	0.018	0.007
Fe	98.92	0.06
Mn	0.898	0.021
Cr	0.051	0.007

RE content are likely to review the potential

**d Cu + Ni + Cr,**  
the type and analytical methods





## Existing Piping Systems ( Retro-Active PMI ) Programs :

### **Priority for API RP 578 2<sup>nd</sup> Edition – “High Temperature Sulfidic Corrosion - API RP 939-C”**

- **Process Units Susceptible to Sulfidation:**

- Carbon Steels with low silicon (0.10%) content can corrode at an accelerated rate
- Assets at risk from this type of degradation should apply PMI control to determine Silicon levels. **(Retro-Active PMI is suggested and to follow API 578.)**
- See API 571 and API RP 939-C
- See Section 7.1.4 & 5



Sample  
Preparation-  
Required

**Low Si-33%, PMI-**

# 1 General Metals		
NAV Tools He: Off		
Time 23.2 sec		
+ LA-4130 0.6		
Ele	%	±2σ
Si	0.252	0.075
Mo	0.210	0.006
Pb	0.053	0.006
Cu	0.158	0.020
Ni	0.132	0.028
Fe	97.18	0.42
Mn	0.578	0.036
Cr	0.973	0.026



## Retro-Active Positive Material Identification PMI API RP-578 2<sup>nd</sup> Edition

Sample  
Preparation  
Required



HF Alkylation Unit  
Retro -Active PMI for  
Residual Elements in  
Carbon Steel API 571



Sample Preparation in HF  
Alky Unit  
Retro -Active PMI



Crude Unit for Low Si-  
API RP-939C  
Retro -Active PMI





## Existing Piping Systems ( Retro-Active PMI ) Programs :

CIU  
Retro -Active PMI



High Temperature  
(450F /232C to 900F/482 C )  
PMI



Remote Access  
Retro -Active PMI



Valves, Pipes, Fittings,  
& Instruments



CCD Camera with  
Small Spot for Welds



Weld Dilution  
Retro -Active PMI





# PMI Field Testing Methods ( XRF or OES )

## Technologies:

### Two Primary Technologies for Portable Elemental Analysis:

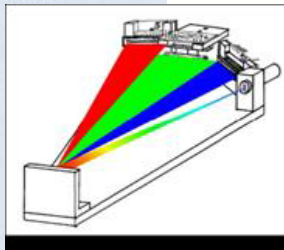
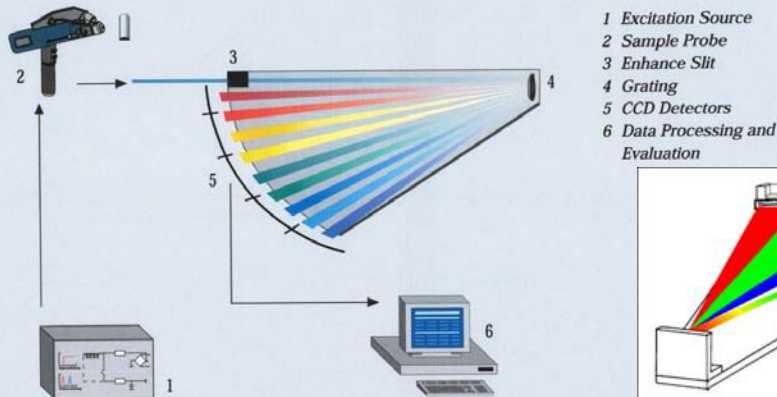
- **X-ray Fluorescence Spectroscopy (XRF)**
  - Technique of exciting and ejecting atoms' inner shell electrons with x-ray radiation and analyzing the fluorescent x-rays emitted when the atoms return to a stable state. X-ray energies emitted correspond to the individual elements, while the intensity is a function of quantity
- **Optical Emission Spectroscopy (OES)**
  - Technique of vaporizing sample surface and analyzing the emitted light spectra. The wavelength of the light corresponds to the elements present, while the intensity is a function of quantity of that element.





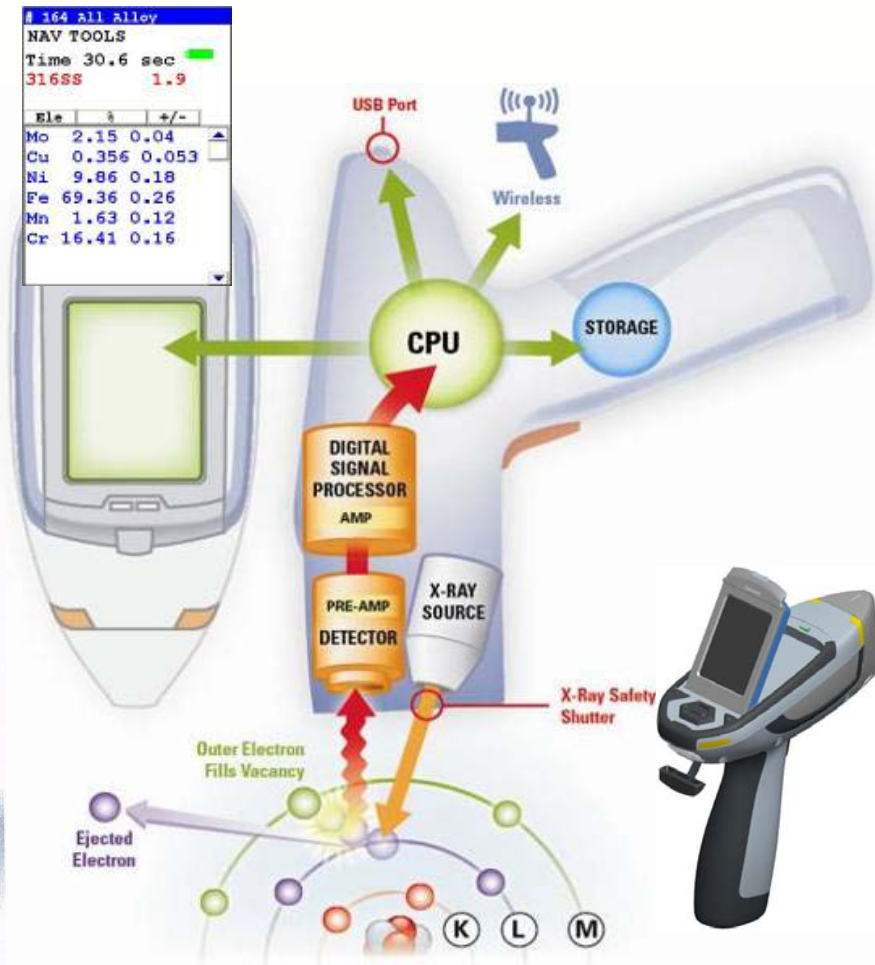
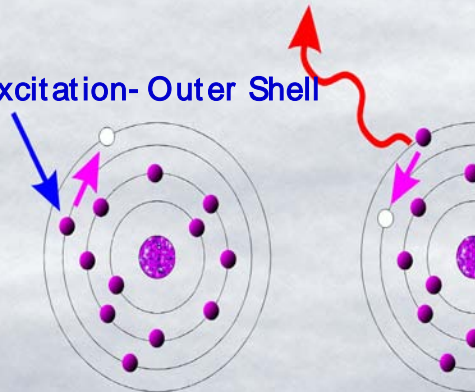
## PMI Field Testing Methods: How XRF & OES Work

Portable and Mobile Metal Analyzer: Working Principle



Emission-Radiated in form of

Excitation- Outer Shell





## PMI Field Testing Methods ( XRF or OES ) Technologies:

### **Pros: Handheld X-ray Fluorescence Spectroscopy**

- Accurate
- Portable
  - the handheld XRF analyzer weighs approximately 1.3 kg (3 lbs.) and is transported in a belt holster at the user's side
- Reduced sample preparation
- Completely nondestructive
- Simplicity
  - XRF technology is much more user-friendly, allowing relatively unskilled operators to participate in the inspection process



### **Cons:**

- Can measure elements only down to Mg on the periodic table (cannot measure carbon)
- Stricter regulation and licensing requirements



## PMI Field Testing Methods ( XRF or OES ) Technologies:

### **Pros: Transportable Optical Emission Spectroscopy**

- Accurate
- Gives visible clue that material has been tested (burn mark)
- Can measure more light elements than XRF (such as C)

### **Cons:**

- Difficulty of transport
  - OES instruments tend to be large and unwieldy, posing access problems in hard-to-reach locations
- Sample preparation
  - the OES testing requires careful preparation of the sample by grinding off the oxide layer and eliminating any pitting or inclusions in the test area prior to analysis
- Damage to the sample
  - the OES test burns and vaporizes a small amount of the sample material, resulting in a heat-affected zone that in some cases must be re-heat treated
- User expertise
  - OES instrumentation requires a high level of user sophistication to maintain calibration, recognize data anomalies, proper surface preparation, etc.







## Control of Incoming Materials & Warehouse



- Should have a MVP associated with Receiving Alloy Materials
- PMI testing May be Performed as Part of the Receiving Function
- PMI Could be Performed at Suppliers Location as a Condition of Release of Shipment
- MVP Should Provide Proper Documentation & Methods for Indicating Which Materials have been Tested and Re-Approved for Use.
- MVP Should Be Regarded as Quality Assurance Practice
- **PMI Testing in Warehouse Should Not be Regarded as Alternative to Field PMI testing**





## Elements of Maintenance Systems for PMI



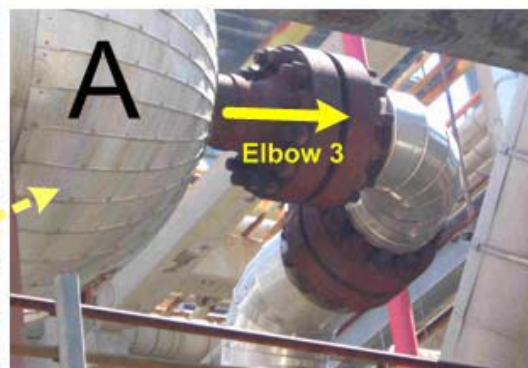
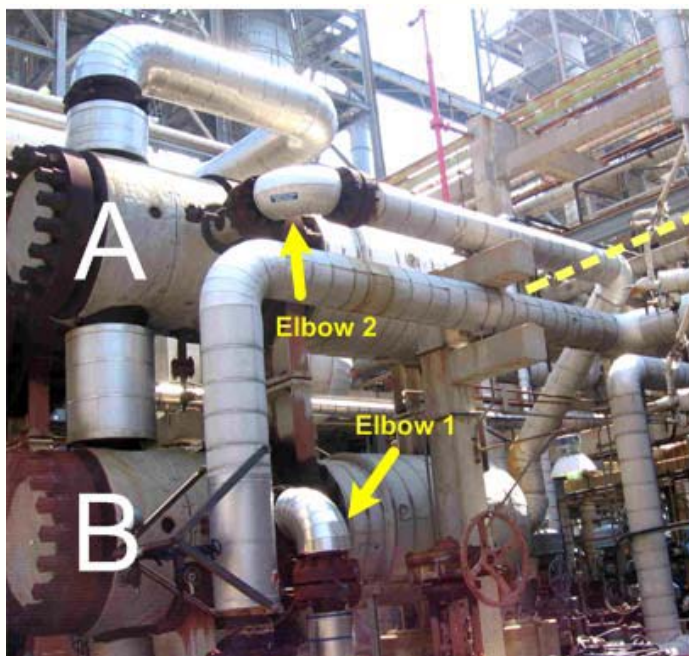
- Temporary Removal of Spool Pieces Need to be Managed in such a way that Material Mix-Ups Cannot Occur.
- Consideration shall be given to a Firm Control System
- A Verification prior to Re-Installation to prevent Mix-Ups Occurring
- Tagging Spools as they are Removed to Ensure Correct Replacement Should be Considered
- PMI After the Repair Procedures to Confirm Proper Alloys were used
- PMI May also Include Components Used
- Consulting with the Inspector prior to Commencement of Work Can Ensure Good Material Control was Enforced





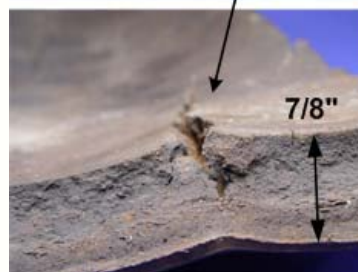
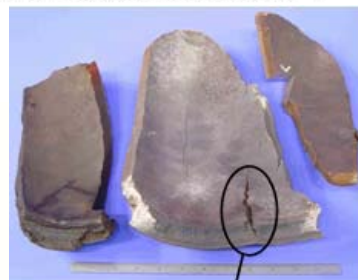
### Elements of Maintenance Systems for PMI

Carbon steel Elbow in a Resid Hydrotreater Unit (RHU) heat exchanger outlet pipe (Elbow 1) ruptured after operating only 3 months in high-temperature hydrogen service. **NO PMI Performed and Elbows Removed without Marking or Tagging !**



Upper left & top arrow – Alloy steel elbows 2 and 3

Lower left arrow - Carbon steel elbow 1



Upper Left – Carbon steel elbow segments (view of inside surface)

Above – Flange segments

Left – Close-up of fissure on middle elbow segment





## Recording & Reporting PMI Test Results

- **Material Certifications:** Material Certifications, mill test reports, or Certificates of Compliance should not be considered a substitute for PMI testing, but may be an important part of an overall quality assurance program.
- **Shop and Field PMI Test Documentation:** Those individuals performing PMI testing should obtain and follow the PMI test procedure approved by the owner/user. This procedure should cover the techniques used, equipment calibration, the qualification requirements of the PMI test personnel, the testing methodology, and documentations requirements. When documentation, such as drawings, is used in lieu of physical marking, the documentation should allow the owner/user to identify which components were tested.
- **New and Existing Piping Systems Documentation:** When PMI testing is conducted on new or existing piping systems, records of the results should be kept as long as the piping system exists in its original location. If a piping system or a portion of a piping system that has not received material verification is relocated, the owner/user should consider the need for PMI testing prior to placing the relocated components into service.



# Recording & Reporting PMI Test Results

API RP 578  
PMI REPORT FORM

Project No.	_____	Client:	_____	Report New Construction	_____
Supplier	_____	PO No.	_____	Report Existing Piping	_____
Distributor	_____	Contact	_____	Report Date:	_____
Visit Date	_____	Phone No.	_____	Shop Ref No.	_____
Drawing No.	_____	OES	_____	Item Tag No.	_____
Model No.	_____	XRF	_____	Performed By:	_____

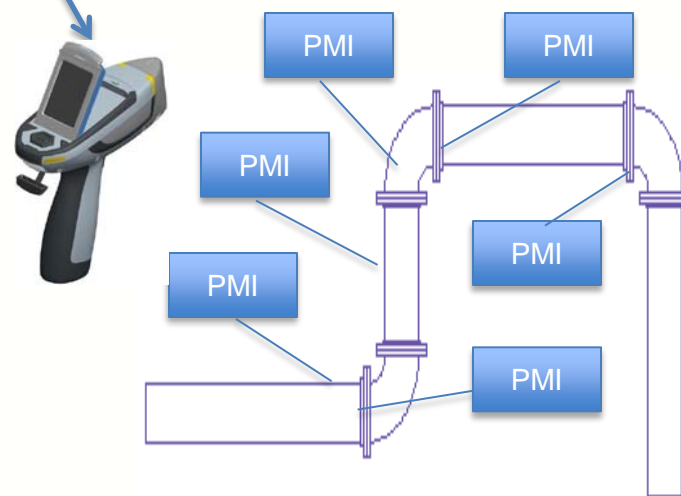
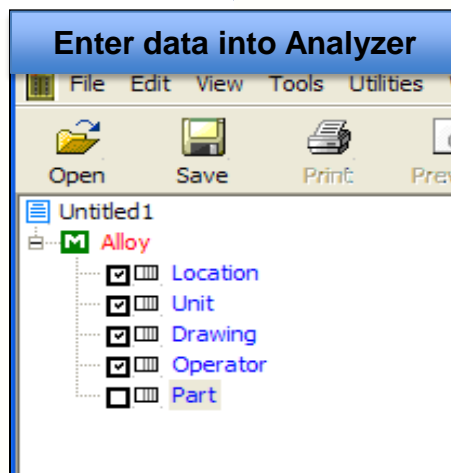
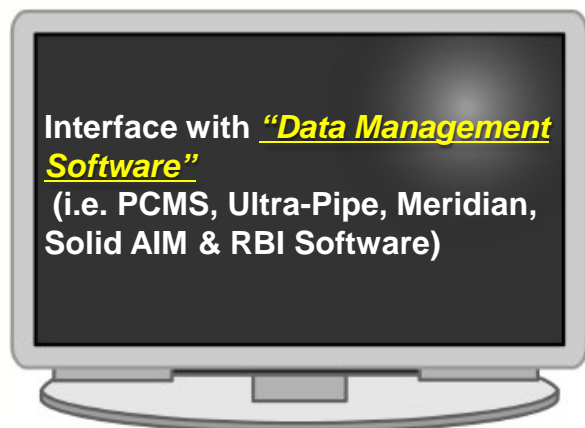
Reading No.	Material Description	Grade of Material	Heat No.	Material Verification Element %	Material Verification Element %	Material Verification Element %	Accept	Reject	Remarks

Action Items for Non-Conformance Material:


*Traceability to Field Components; the information listed in "PMI Test Records" should be reported in such a manner that they are traceable to the point of installation.*

*The best way to tie the "Report Documentation" to the field PI&D or ISO drawings, is to mark the drawings ( Electronically or Manually) and enter this (drawing number) in the XRF/OES Analyzer.*

*It is strongly suggested that you keep both paper and electronic files on this documentation.*







# Conclusion :

- Introduction
- New Construction- QA/MVP Programs
- Existing Piping Systems ( Retro-Active PMI ) Programs
- PMI Field Testing Methods ( XRF or OES ) Technologies
- Control of Incoming Materials & Warehouse
- Elements of Maintenance Systems for PMI
- Recording & Reporting PMI Test Results
- Conclusion ( Questions & Answers )



## Questions & Answers?

### Don Mears

Analytical Training Consultants &

Thermo Scientific Niton XRF Analyzers

1719 Burning Tree, kingwood, Texas ( USA) 77339

Web: [www.ATC578.Com](http://www.ATC578.Com)

[Don@ATC578.Com](mailto:Don@ATC578.Com) or [Don.Mears@Thermofisher.com](mailto:Don.Mears@Thermofisher.com)

Phone: +1 (281) 684-8881



*Niton XRF Analyzers*



**API/TPCP -0118**

