# Appendix 5

# Advanced Weld Overlay Technology for Pressure Vessels & Boilers with presentations of history cases in Refineries

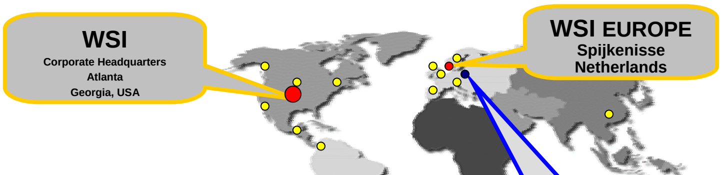
**Andrea Pacchiarotti**

**(Aquilex Welding Services)**

**WSI Welding Services Inc.**

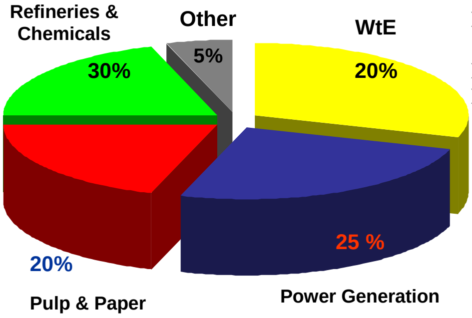
# Advanced Weld Metal Overlay Technology for Pressure Vessels & Boilers with presentations of history cases


*Mike Welch - Aquilex Welding Service U.S.A.*
*George Lai - Aquilex Welding Services Consultant*
*Andrea Pacchiarotti –Aquilex Welding Service s Italia*


*25 years experience in Automated Welding*

- **Design and Build automated Welding Equipment**
- **130’000 m$^2$** of weld overlay
- **1.8 milions of Kg Wire applied**




- **Logistic Headquarter** in The Netherlands and **Manufactory Facility** in Poland
- **600** plus trained and qualified weld operators
- Officies in several Countries around the world

***Yearly Performances:***

**500 Projects**

**300** emergency *on site* job

**20’000 m$^2$** of *weld overlay*

## What is Weld Overlay ?

- **In the past,** Weld Overlay was considered to be a temporay Repair Solution

- **Today, Weld Metal Overlay** (***Unifuse® Solution*** by WSI) is an advanced welding technology that delivers Permanent Repair & Upgrade Solutions (*it permits to your plant to reach higher performances)*

***Unifuse***® **Weld Overlay is**:

*A System Developed Approach to provide Corrosion or Erosion/Corrosion Protection for Major industrial Process & Boiler Plant*

## Where is weld overlay a repair / upgrade solution ?

| Alloy | Component Weld Overlay Applications |
|---|---|
| ER309L | External Weld Overlay for Atmospheric Protection |
| ER317L | Vessel Weld Metal Overlay<br>Naphthenic Acid Corrosion |
| Monel 400 | Vessel Weld Metal Overlay<br>HF Service Applications |
| Inconel 622<br>Inconel 625 | Sulphur Corrosion Applications, Low Ph and high Erosion application |
| Hastelloy C-2000<br>Hastelloy C 276, C 22 | Low Ph agreessive chemical process protection |
| 2205 – 2209, 312 | Duplex and Super Duplex SS for Vessel Overlay |
| ER70S-7 | Carbon Steel Build-Up for Wall Restoration |

- **Weld Metal Build-up**

One or more layers of weld metal applied to the base metal to obtain desired properties or dimension.

- **Corrosion Resistant Overlay**

Dissimilar weld metal deposit on base metal to deter corrosion/erosion.

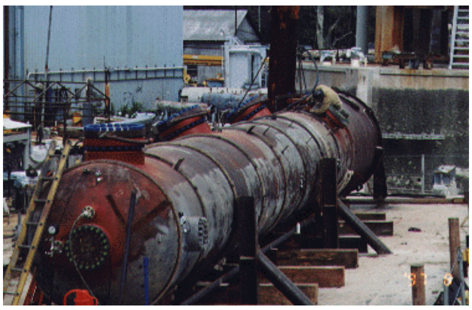
## *Unifuse*® Weld Overlay

- *Pulse Spray Gas Metal Arc Welding* (PSGMAW)
- Higher Welding Speed compared to automatic equipments
- Fully Automatic & Programmable Machines
- Multiple Machines Operate Simultaneously
- Consistent welding Parameters & Quality
- Broad selection of Alloys Available
- Closed-Loop Process Control

## Weld Parameter Controls

*Closed-Loop Process Control*

- GMAW: Wire Speed, Volts, AHC
- GTAW: Wire Speed, Amps, AVC
- Deposition Rate
- Heat Input
- Bead Placement

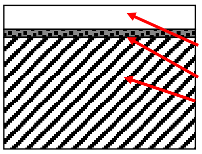


Microstructure Density

Alternative

*Unifuse®* weld overlay

## *Unifuse®* Quality



### Composition

1. Homogenous Overlay, < 7% Diluition
2. Fusion Boundary, < 10 - 12% Diluizione
3. Metallo Base

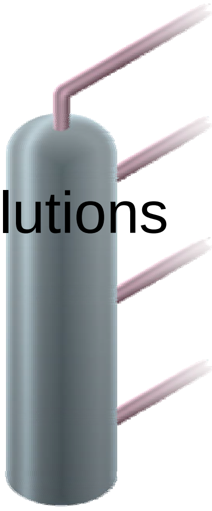
# Process Characteristics

| | *Unifuse®* 180 | *Unifuse®* 360 | SMAW |
|---|---|---|---|
| Total Heat Input (Joules/Sq.Ft) | 450,000 | 400,000 | 1,600,000 |
| Thickness Tolerance (mm) | .010 | .005 | 0.20 |
| Depth of HAZ (mm) | Low .010 | Low .010 | High .040 |
| Surface Profile | Smooth | Extremely Smooth | Rough |

** Alloy 625, wire data*

| Temperature (°C) | Tensile Strength MPa | Yield Strength at 0.2% | Elongation in 2.0 in. |
|---|---|---|---|
| Room | *786 (905)** | *460 (490)** | *54 (48,5)** |
| 315 | *660* | *383* | *45* |
| 426 | *645* | *376* | *53* |
| 537 | *614* | *360* | *48* |
| 650 | *600* | *354* | *42* |

## Pressure Vessel Solutions

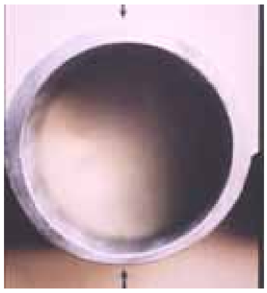


## Reliability Considerations

- Environmental Driven Modifications
- Feed Stock Changes
- Design Modifications
- Life Extension
- Corrosion Under Insulation (CUI)

## Options?

- Component Replacement
- Mechanically Bonded Linings (No Restoration Strength)
  - –Refractory
  - –Thermal Spray
  - –Strip Lining
- Manual “Pad” Welding



## The WSI Solution

# ***Unifuse®***

# What is ***Unifuse***®?

- ***Unifuse***® **is:**
  - A Comprehensive Program for Delivering Optimized Automated Weld Overlay Performance Properties.

Vertical Down

Horizontal

# *Unifuse*® Technology

- Applies optimal weld chemistry
  - Controls all weld parameters
  - Lowest dilution achievable
  - Real-time display
- Recent improvements
  - PLC Controlled
  - Proportional Automatic Height Control
  - Proprietary Wire Feed System
  - Watchdog system

# *Unifuse*® Technology

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  - Lowest dilution achievable
  - Real-time display
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  - PLC Controlled
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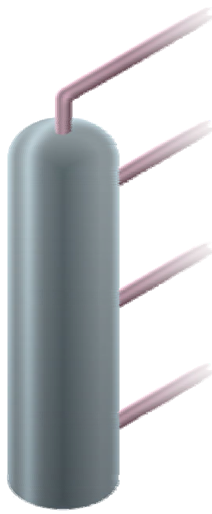
  - Proprietary Wire Feed System
  - Watchdog system

# Typical Applications

- Vessels
- Towers
- Columns
- Bottom & Top Heads
- Transitions
- Nozzles
- Heat Exchangers
- Horizontal Drums
- ID Piping
- OD Piping
- Plate for Fabrication



# History cases

## Unifuse® for Insulation Corrosion

- **Facility : UK Refinery**
- **Plant Item : Coking Vessel**
- **Damage : Under Insulation Corrosion**
- **Location : Knuckle of top dome**
- **No. of Vessels : 2**
- **Vessel diameter : 6.2 mtrs**
- **Overlay Area : 20 m$^2$ per vessel**
- **Overlay thickness : Minimum 7.0 mm**
- **Material : Carbon Steel**
- **Program : 9 days utilising multiple automatic welding systems**

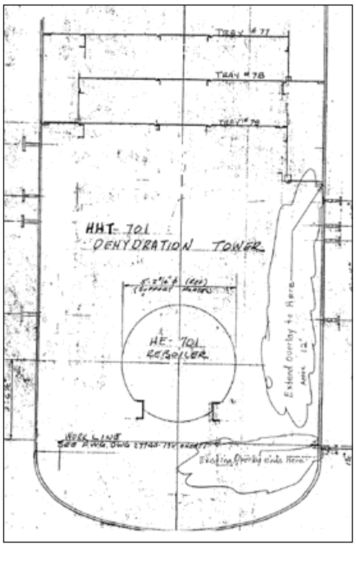
# Unifuse® for Insulation Corrosion

# Repair of Solvent Dehydration Tower

BP Amoco – Decatur Refinery

# Customer Challenge

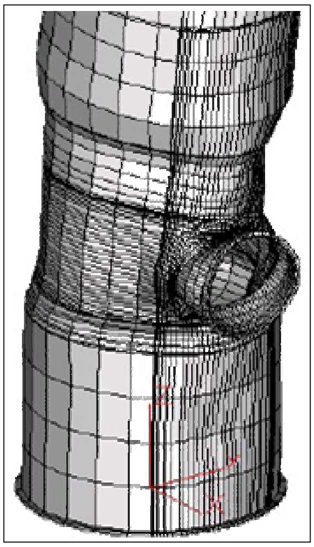
- Solvent dehydration tower
- Tower details:
  - SA-240-316L material
  - 165 foot tall
  - 13 foot ID
  - Original wall thickness 0.800”
- Turnaround inspection:
  - Reveals corrosion of bottom section due to chemical attack
  - Vessel wall thickness as low as 0.250”
- Issue:
  - 62” opening in the middle of the overlay zone



# Customer Challenge

Client options:

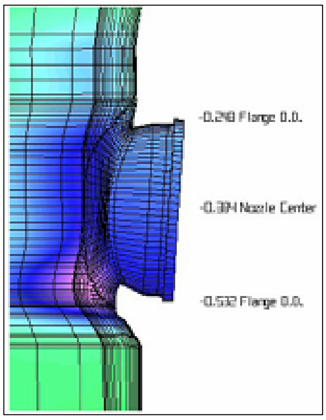
- Replacement:
  - Lead time: 8 months
- Pad welding:
  - Already been done by general contractor with long schedule & poor quality
- Weld overlay concerns:
  - Distortion of manway



# WSI Approach

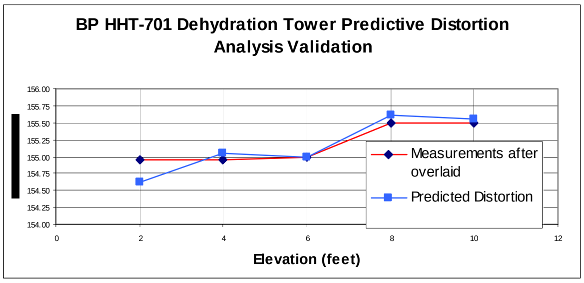
Engineered Repair Design:

- Perform Finite Element Analysis of overlay zone
- Prediction:
  - No distortion beyond design engineered limitations
  - Deflection of manway to be less than 1%
  - Application methodology optimized for safety, quality, and productivity



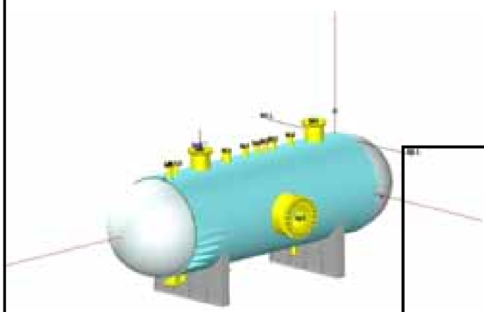
# WSI Approach

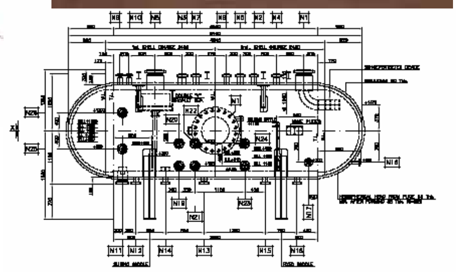
- Restored pressure boundary with two layers of 316L
- Applied Alloy 625 over buildup areas as well as lower vessel section
- Results
  - Model within 1% of measured distortion
  - Cost savings of over $2.5 million
  - Time savings of over 1 week




# Horizontal Weld Overlay

**Separators**





## Horizontal Weld Overlay

## Horizontal Weld Overlay

# Horizontal Weld Overlay

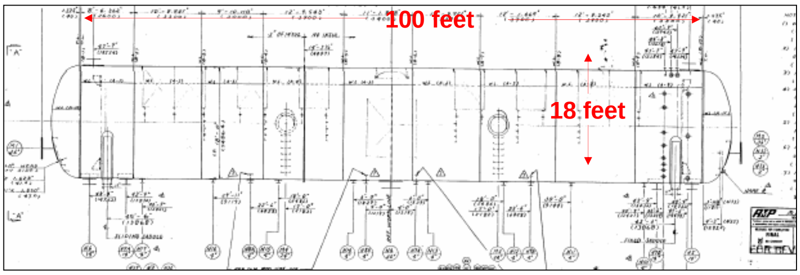
**Automatic Overlay inside Vessel bores and nozzles**

# Horizontal drum repair

BP-Amoco - Prudhoe Bay
Upstream Facility

## Customer Challenge

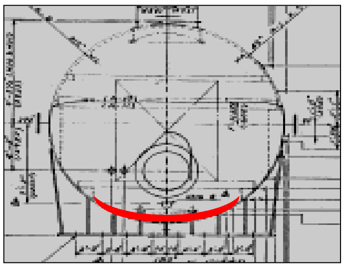
- Upstream facility in Alaska
- Slug Catcher: ASME Section VIII, Div 2 pressure vessel
- Corrosion on bottom 1/8 of entire vessel length
- 800+ square feet below minimum wall thickness
- Schedule, schedule, schedule: Any downtime associated with component shut down the entire plant




## Customer Challenge

Client options:

- Pad Weld:
  - Schedule: unknown
  - Quality: unknown
  - Post weld heat treatment required
- Automated Unifuse weld overlay
  - Schedule: less than 40 days worst case
  - Quality: Unifuse technology
  - Post weld heat treatment eliminated through temper bead
    - WSI Welding Engineering developed appropriate weld procedures



# WSI Solution

Weld procedures:

- Groove
  - Temperbead GMAW buildup with ER70S-7 (2 layers)
  - GMAW buildup with ER70S-7 (1 layer) & ER309LSi temperbead
  - SMAW E7018-H4 buildup on nozzle/shell intersections
- Corrosion-resistant overlay
  - GMAW ER309LSi
  - GTAW ER309L for nozzle overlays

Page 1 of 4 — WELDING PROCEDURE SPECIFICATION — WPS 01-01-G-631 Rev. 0

Company Name: Welding Services, Inc. By: [signature] QA: [signature]
Welding Procedure Specification No. WPS-01-01-G-631 Date: 08/17/2001
Revision No. 0 Date: 08/17/2001
Supporting PQR No.(s) PQR-01-01-G-630
Welding Process(es) GMAW Type(s) Semi-Automatic, Machine

**BASE METALS (QW-403)**
P-No. 1 Group No. 1 or 2 to P-No. 1 Group No. 1 or 2
OR Specification type and grade to Specification type and grade
OR Chem. Analysis and Mech. Prop. to Chem. Analysis and Mech. Prop.
Base Metal Thickness Range: Groove 0.1875" – 1.5" Fillet All
Pipe Dia. Range: Groove All Fillet All
Other: See Note 2 and 6 for material restrictions when this WPS is used in applications governed by NBIC RD-1040 (Welding Method 2)

**JOINTS (QW-402)**
Joint Design: Temperbead groove
Backing (other than gas backing) required? ☒ Yes ☐ No
Backing Material (Type): Base material serves as backing
Retainers: ☒ Not Permitted ☐ Permitted
Other: None

**PREHEAT (°F) (QW-406)**
Preheat Temp. Min. 50°F
Interpass Temp. Max. 450°F
Preheat Maintenance: ☐ No ☒ Yes
Preheat Notes: Preheat 30 minutes (min) prior to weld start. Maintain preheat for the duration of weld installation.

**POSITIONS (QW-405)**
Position(s) of Groove: All
Welding Progression: ☐ Up ☒ Down
Position(s) of Fillet: All

**PWHT/POSTWELD HEAT SOAK**
Temperature Range: NA
Time Range: NA
PWHT Notes: Post soak is not required. PWHT is not permitted (QW-407)

**ELECTRICAL CHARACTERISTICS (QW-409)**
Current: ☐ AC ☒ DC Polarity: ☐ Straight ☒ Reverse
Amps (Range): See pg. 2 Volts (Range): See pg. 2
Tungsten Type: None Size: NA
GMAW Xfer Mode: Spray or Pulsed Spray
Maximum Heat Input: See page 2

**GAS (QW-408)**

| | Gas(es) | Mixture | Rate (CFH) |
|---|---|---|---|
| Shielding (Layer 1) | Argon/CO2 | [illegible] | 32-75 |
| Shielding (Remainder) | Argon | NA | 32-75 |
| Backing | None | NA | NA |

**FILLER METALS (QW-404)**

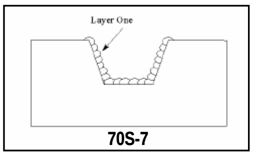
| | Layer 1 | Layer 2 and Remainder |
|---|---|---|
| Spec. No (SFA) | SFA 5.18 | SFA 5.9 |
| AWS Class | ER70S-7 | ER309LSi |
| F-No. | F-6 | F-6 |
| A-No. | NA | A-8 |
| Filler Size | See Page 2 | See Page 2 |
| Weld Metal Groove Thk Range | 0.0" – 0.250" (One Layer) | 0.0" – 1.5" |
| Fillet Thk Range | 0.0" – 0.250" (One Layer) | All |
| Flux Class | None | None |
| Flux Trade Name | NA | NA |
| Consum. Insert | ☐ Permitted ☐ Not Permitted ☒ NA | ☐ Permitted ☐ Not Permitted ☒ NA |
| Insert Materials | None | None |
| Other | NA | NA |

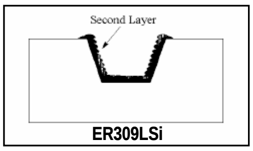
**TECHNIQUE (QW-410)**
String or Weave Bead: ☐ String ☐ Weave ☒ Both ☐ Other (explain)
Orifice or Gas Cup Size: Cup sizes # 4 through # 14 permitted
Initial and Interpass Cleaning: ☒ Mechanical ☒ Thermal Grind to bright metal after thermal gouging
Method of Back Gouging: ☒ Mechanical ☒ Thermal Grind to bright metal after thermal gouging
Oscillation (Machine/Auto Only): Permitted (1.250" Maximum)
Contact Tube to Work Distance: 0.50" Minimum, 1.25" Maximum
Multiple or Single Pass (per side): ☐ Single ☒ Multiple
Multiple or Single Electrodes: ☒ Single ☐ Multiple
Travel Speed (Range): See Page 2
Peening: ☒ Prohibited ☐ Permitted (explain)
Welding without filler material: ☒ Prohibited ☐ Permitted (explain)
Supplemental filler material: ☒ Prohibited ☐ Permitted (explain)
Qualified for Impact Test Apps.: ☒ Yes ☐ No
Pass exceeding 1/2" permitted: ☐ Yes ☒ No

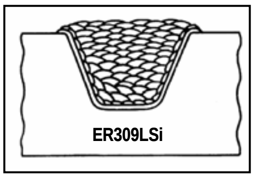
# WSI Solution

Implementation Plan:

- Vessel prepared by others
  - Internals removed, hydrogen bakeout
- Sandblast vessel
- Perform visual & UT inspection
- Surface preparation by grinding and gouging
- Perform weld metal build-up
  - Areas requiring one layer of 70S-7 buildup uses one layer of ER309Lsi for tempering (shown on the right)
  - Areas requiring two layers of 70S-7 buildup uses 70S-7 for temperbead
- Perform visual & UT inspection of buildup areas
- Perform ER309LSi overlay on areas:
  - Two layers of 70S-7
  - No base metal buildup



# WSI Solution

Results:
- Schedule: work completed in vessel in only 34 days
- Production loss nominal based on project occurring during a planned turnaround
- Zero wall wastage to date

# Weld overlay repair of high pressure separator vessel

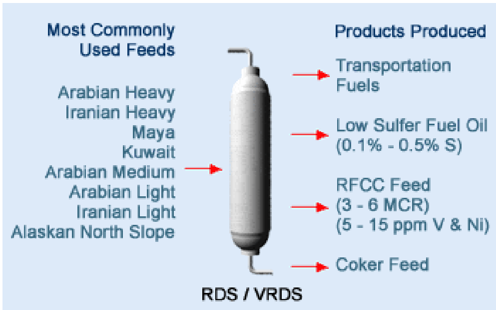
ChevronTexaco

El Segundo Refinery

# Customer challenge

- VRDS Plant (Vacuum residuum desulfurization)
- Critical component in unit

- High Pressure Separator
  - SA 516, Grade 70
  - 6’ diameter
  - 43’ tall
  - 5.5” thick




# Customer challenge

Customer issue:

- Belzona installed 18 months earlier
- Visual inspection reveals Belzona is falling off
- Bottom third of vessel requires repair
- Wall thickness below t-min
- Schedule, schedule, schedule


# Partial Customer List

| | | |
|---|---|---|
| Allied Signal | ConocoPhillips | Lyondell Chemical |
| Amerada Hess | Eastman Chemical | Marathon Ashland |
| Aristech Chemical | Equistar | Methanex |
| Arizona Chemical | ExxonMobil | Millennium Chemical |
| BASF | Farmland Industries | Monsanto Chemical |
| Bayer Chemical | Flint Hill Resources | Noveon |
| BP Amoco | Formosa Plastics | Oxychem |
| Chalmette Refining | GE Plastics | PDVSA |
| ChevronTexaco | Goodyear | Pennzoil |
| ChevronPhillips | Hunt Refining | Phillips 66 |
| Citgo Petroleum | Huntsman Chemical | Tesoro Petroleum |
| Clark Refining | LaRoche | Shell Oil |
| Coastal USA | Linde Gas | Sunoco |
| Coastal Aruba | Motiva | Valero |

# WSI Solution

- Client contacts WSI
  - WSI on-site in 48 hours with supervision
  - Equipment on-site within 72 hours
- High preheat of 250ºF required
  - Safety plan developed to ensure safe work environment

# WSI Solution

- Project Execution
  - Removed Belzona by grit blasting
  - Grinded out pits
  - Performed weld buildup on 150 $ft^2$
  - Provided corrosion resistant overlay on 300 $ft^2$
- Executed project in 10 days

# Catalyst Tube Flange Repair

Suncor – Sarnia Refinery

# Customer Challenge

- Methane Steam Reformer Furnace
  - 156 HP35 Catalyst 3” Tubes
- Client Issue: Cracking of Lower Flange weld
  - HP35 to Carbon Steel
  - Limited access for manual welding
  - Caused by low temperature condensation – resulting in oxidation

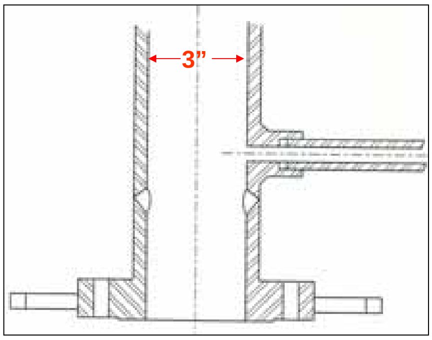
# Customer Challenge

- Additional concerns
  - Cracking in the original weld
  - Corrosion around original weld area
- Client options
  - Complete replacement of catalyst tubes
  - Dismantle lower furnace to create access for manual welding
  - WSI approach

## WSI Solution

WSI Alternative:

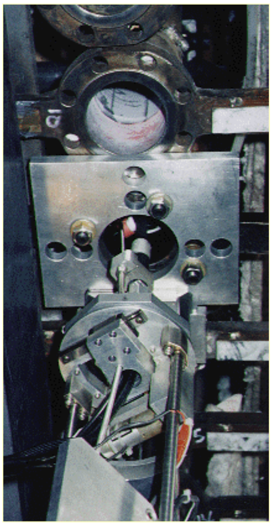
- Perform weld from the inside of the tube
  - Utilize ID machining tool
  - Cut existing flange and perform new weld prep in one step
  - Install new flange with auto GTAW ID weld head




## WSI Solution

WSI Approach:

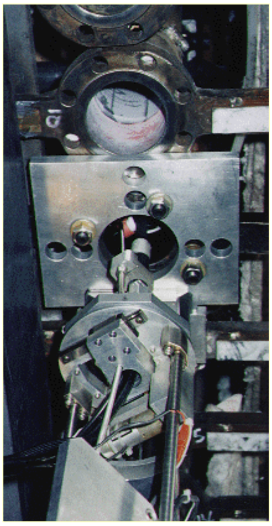
- Developed an integrated tool to perform the machining and welding
- WSI used a consumable insert to make the root pass
- Equipment is not commercially available for purchase



## WSI Solution

Results:

- Inspections showed 77 flanges needed to be replaced
- WSI handled all machining and welding
- Four integrated systems completed the work in 4 days
- ID of tube weld overlaid with alloy 625 with same system
- Zero rejects



## Heavy Wall Piping

- Seamed hot reheat piping replacement
- P-91 material
- Worked performed from 2000 to 2002
- 170 Critical joints
  - Ranged from 18” diameter to 32” diameter
  - Three small rejects

# Partial Customer List

| | | |
|---|---|---|
| Allied Signal | ConocoPhillips | Lyondell Chemical |
| Amerada Hess | Eastman Chemical | Marathon Ashland |
| Aristech Chemical | Equistar | Methanex |
| Arizona Chemical | ESSO Refinery | Millennium Chemical |
| BASF | ExxonMobil | Monsanto Chemical |
| Bayer Chemical | Farmland Industries | Noveon |
| BP Amoco | Flint Hill Resources | Oxychem |
| Chalmette Refining | Formosa Plastics | PDVSA |
| ChevronTexaco | GE Plastics | Pennzoil |
| ChevronPhillips | Hunt Refining | Statoil |
| Citgo Petroleum | Huntsman Chemical | Tesoro Petroleum |
| Clark Refining | LaRoche | Shell Oil |
| Coastal USA | Linde Gas | Sunoco |
| Coastal Aruba | Motiva | Valero |

# Appendix 6

# Thermal spray coatings

## Dave Harvey (TWI)

EFC-NACE Italia Section Joint Meeting, Venezia 31 March 2006

# Thermal Spray Coatings


**David Harvey**

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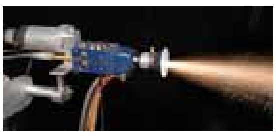
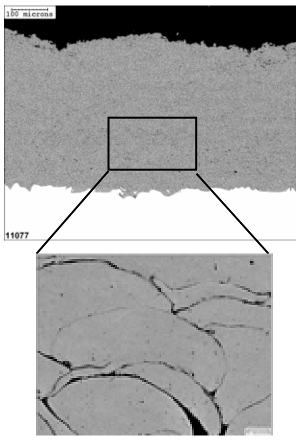
**tel +44 1223 891162**

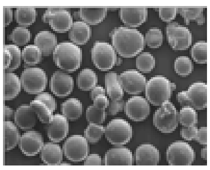

# Thermal Spraying

**Wire**

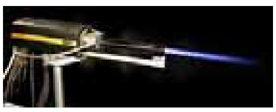


**Electric arc**





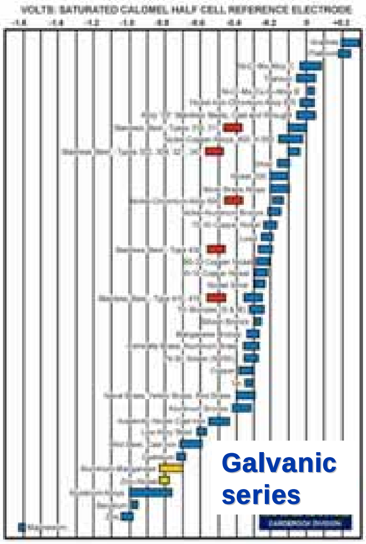
**Powder**



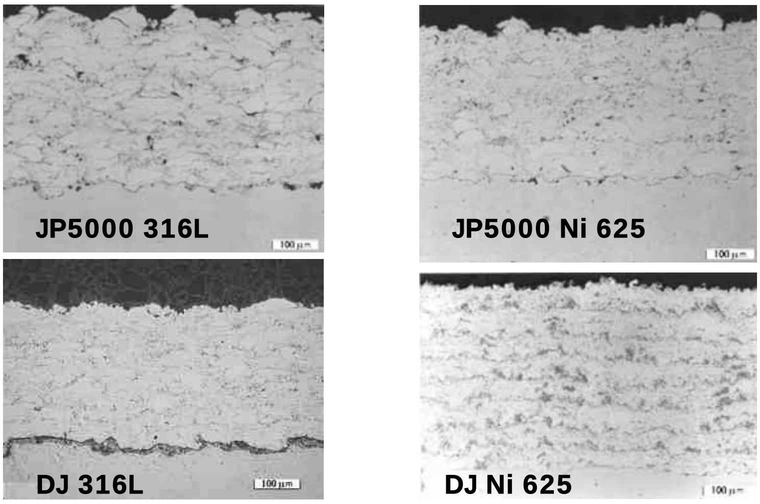
**Flame**

# TSCs for Corrosion Mitigation

- "Anodic" materials such as Al, Zn etc protect carbon steel
- "Noble alloy" coatings must provide a physical barrier between substrate and corrosive medium

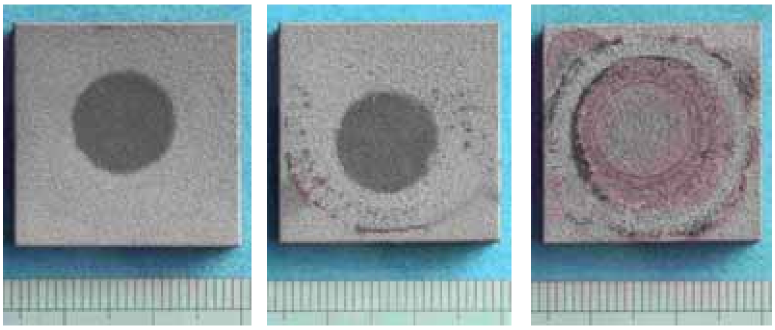



# HVOF Stainless Steel 316L Coatings

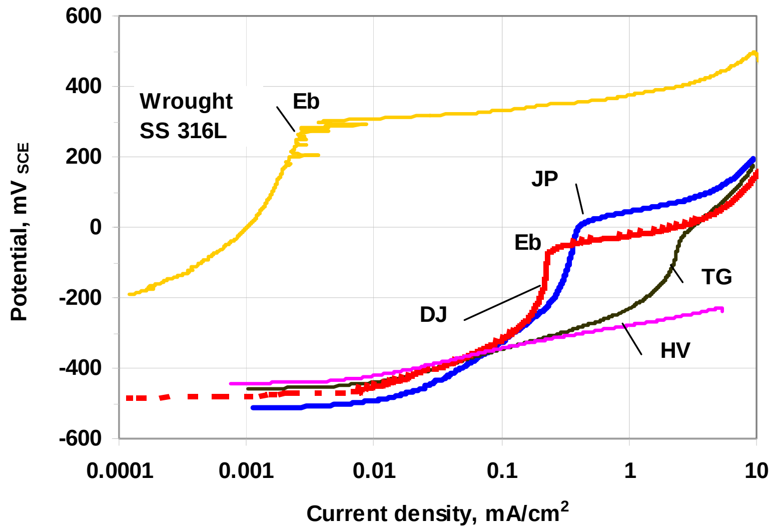


# Ni Alloy Coatings

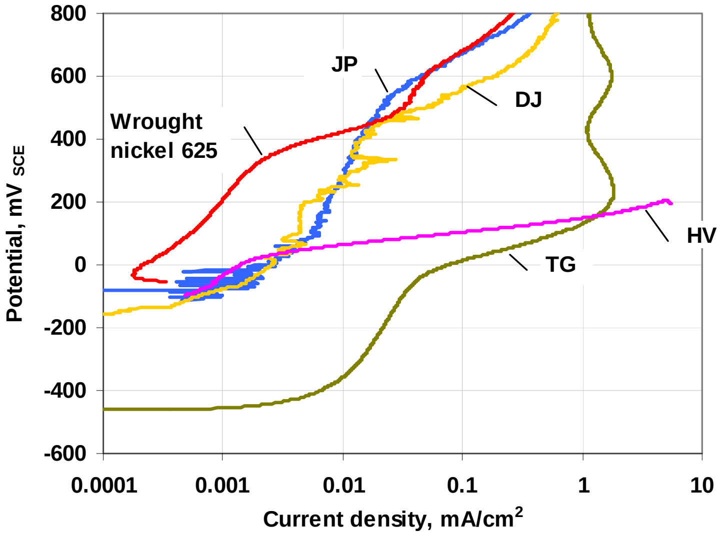
**Surface after corrosion testing**



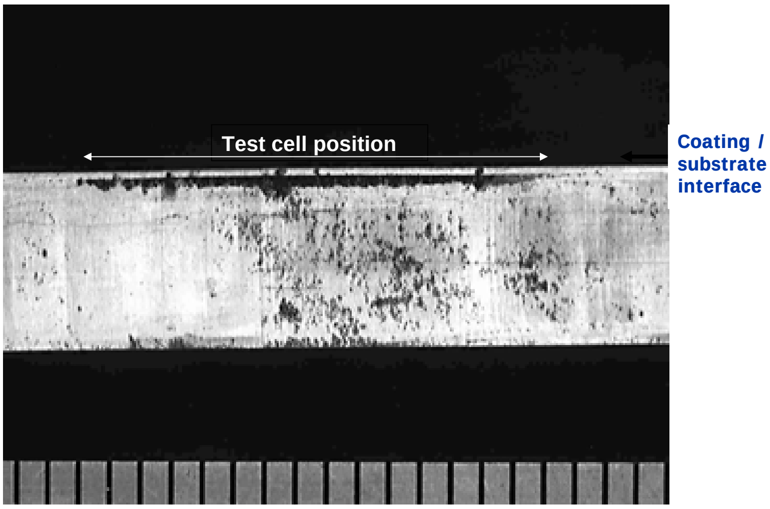
# Stainless Steel 316L



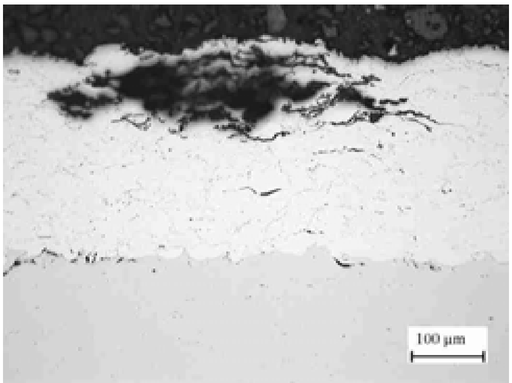
# Ni Alloy 625




# Pitting corrosion in substrate



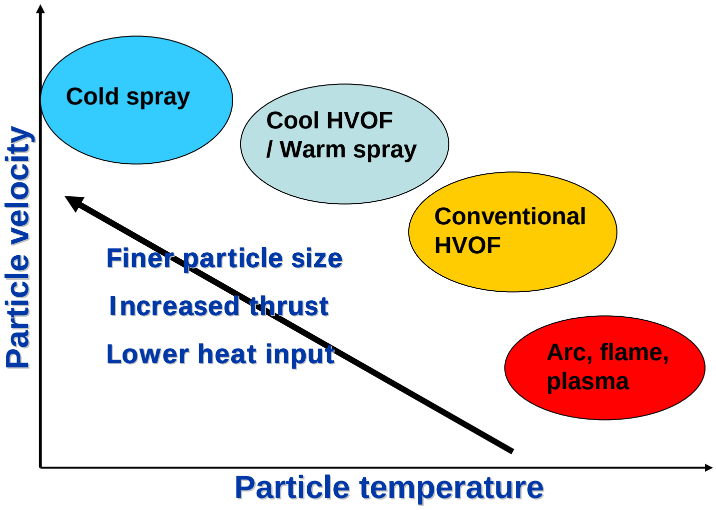
## Nickel Alloy 625 Coatings




**Localised corrosion attack of coating extending along inter-particle (splat) boundaries**

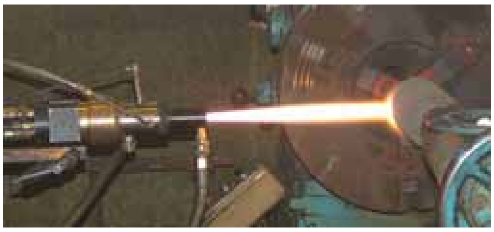
**No penetration through coating or corrosion of underlying steel substrate (in this example)**

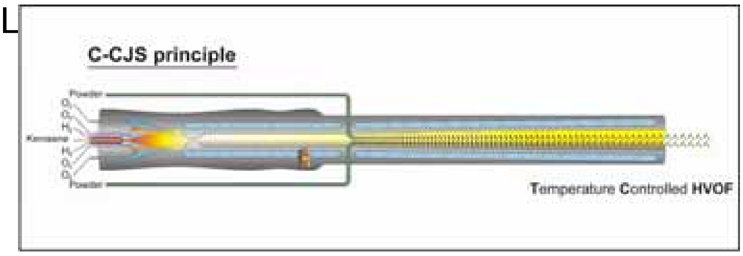
## Spray Technology Position



# Fine Powder Cool HVOF (C-CJS)

- Very fine powders
- Very high particle velocity
- $H_2$ atomised kerosene fuel
- L

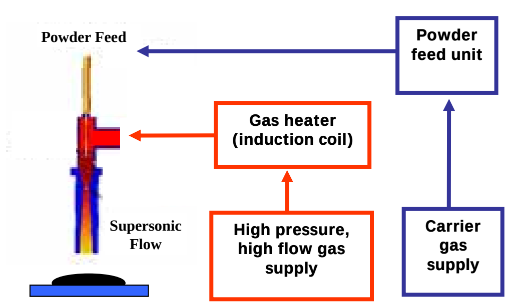




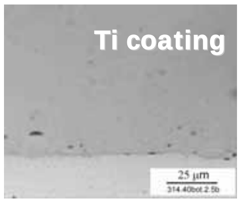

# ID CoolFlow Internal HVOF Process

- Superfine powders need less thermal energy
- Shorter stand-off distance

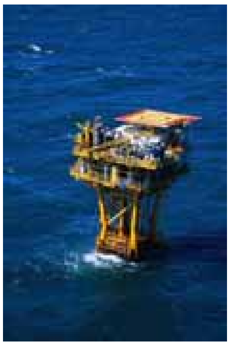
# Cold Spray System

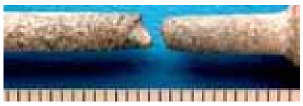


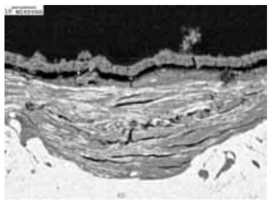


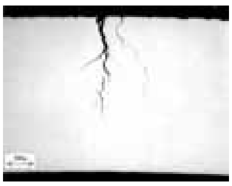


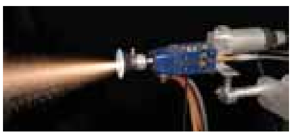

# Mitigation of Corrosion using Thermally Sprayed Aluminium (TSA)

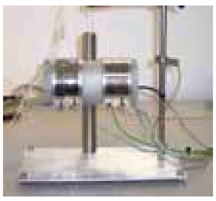








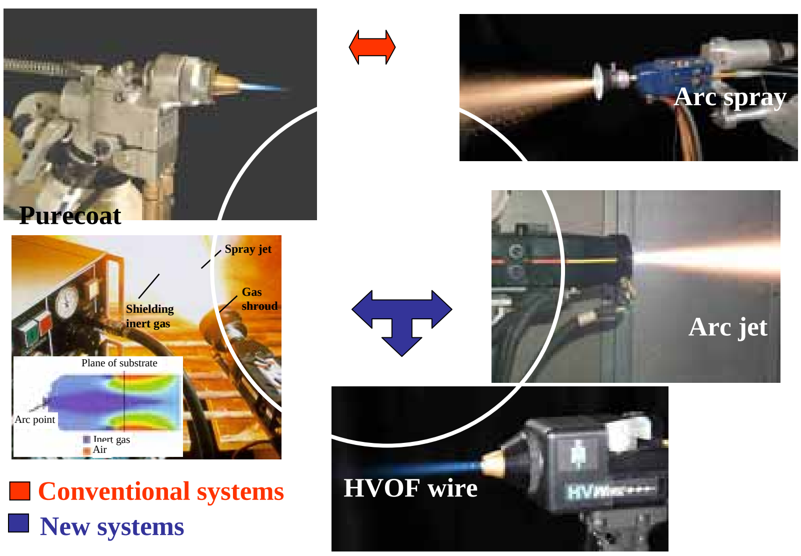




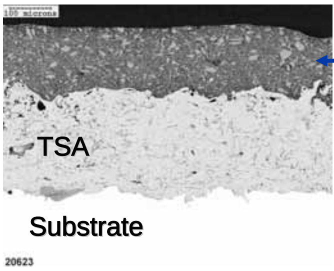
# TSA Joint Industry Projects

- Current & completed projects: (primarily offshore)
  - JIP 13458: Improving the reliability and cost performance of TSA on C-steel (completed April 2003)
  - JIP 14661: TSA coatings for prevention of corrosion of 22Cr DSS at elevated temp. (completed May 2005)
    - **Use of TSA to mitigate CUI for 22Cr DSS and 316L SS**
  - PR 9232: TSA coatings for prevention of corrosion & EAC of welded CRAs (25Cr SDSS, 22Cr DSS, 12Cr SMSS, 316SS)
- New projects - most relevant to the Refinery Industry:
  - PR 9483: Prevention of corrosion under insulation (CUI) of steel with TSA (launch May 2005)
  - PR 10419: Thermal spray coatings for corrosion mitigation: State-of-the-art (launch May 2005)

# JIP13458: Thermal Spray Process Benchmarking Study

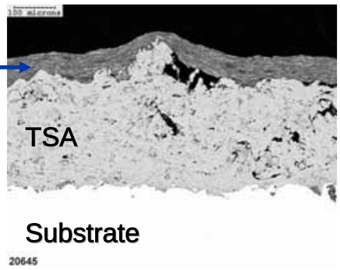


## JIP 13458 & JIP14661: Performance of Sealed TSA Coatings

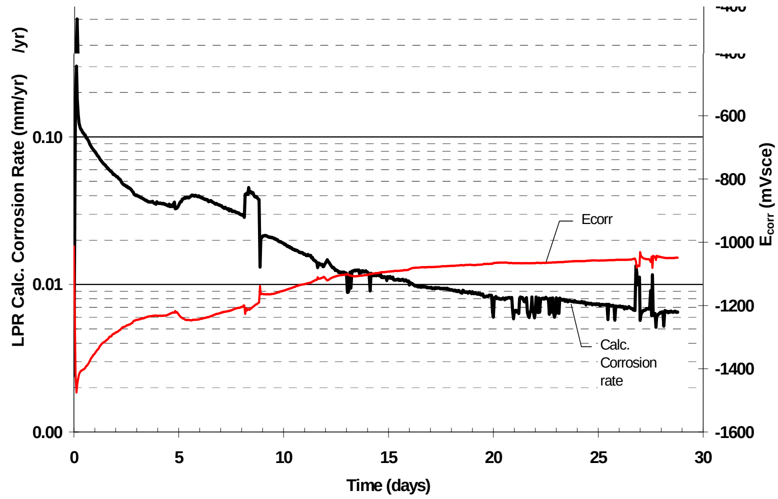



Polyamide epoxy sealant

Aluminium silicone sealant

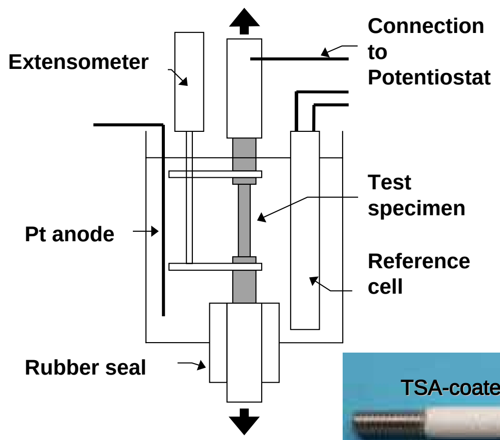


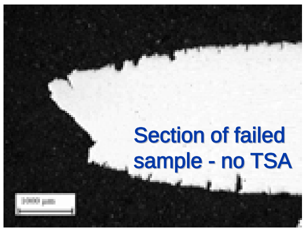

## $E_{corr}$ and Corrosion Rate of TSA

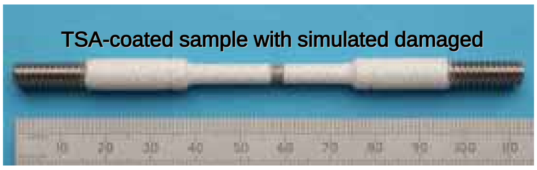



- $E_{corr}$ ~ 1050mV$_{sce}$ and CR of TSA stabilise after about 15-20 days
- Stable corrosion rate of TSA ~ 6-8$\mu$m.yr$^{-1}$ in seawater at 80°C, pH 7.8-8.0

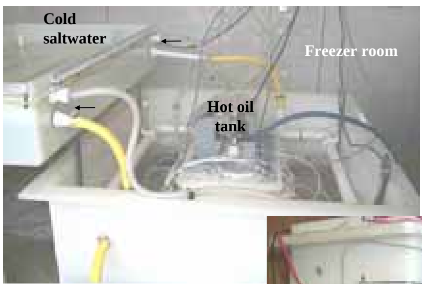
# HISC Test




# JIP13458: High Temperature Seawater Test Rig





# TSA Review - Joint Industry Project

- PR10419: Thermal spray coatings for corrosion mitigation: State-of-the-art (launch May 2005)
- Objectives:
  - State-of-the-art report, experie[illegible]ncerns
  - Best practice guidelines
  - Benchmark technically & econ[illegible]y
  - Identify technology gaps
- Work scope:
  - Assets and components
  - Service duty and environment
  - Standards and codes of practice
  - Thermal spraying processes & materials
  - Application issues, health & safety and environment, QA/QC

# Appendix 7

# The role of technical societies and working parties in the management of knowledge

**Giovanna Gabetta (ENI E&P)**

**MarinoTolomio (VeneziaTecnologie)**

# The role of technical societies and working parties in the management of knowledge

Giovanna Gabetta, Eni Div. E&P
Marino Tolomio, VeneziaTecnologie

**Refinery Corrosion Working Party**
**EFC & Nace, Italy Section**
**March 31, 2006**



Knowledge Management Portal

## Knowledge Management

- New information systems and tools, new communication facilities increase the amount of information available at a speed that was not conceived until a few years ago
- Increasing importance to "intangible assets" and knowledge - essential for the competitive advantage
- There is a need to find, select, organize, elaborate, and present information in a way that improves the performance of employees and organizations in a specific area of interest

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Eni's Way

Knowledge Management Portal

- Knowledge management (KM) helps an organization to gain insight and understanding from its own experience

- Specific KM activities help focus the organization on acquiring, storing, and utilizing knowledge for such things as problem solving, dynamic learning, strategic planning, which are in summary a support to decision making

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Knowledge Management Portal

## KNOWLEDGE

- *Explicit*, or *Codified Knowledge:* information and rules mainly in written form, as for instance project reports, contracts, process diagrams, lists, and explanations of lessons learnt and case studies, with books, manuals, company standards, and best practices, in summary documents and publications easily searchable, in addition to data and information with high added value, particularly those which come from experience internal to the system.
- *Tacit*, or *Personal Knowledge* is not codified, difficult to become formal, based on practical experience, short-lived and volatile. It is based in the knowledge patrimony of people, and people only can make it explicit via direct contact with other people. It is a weak but important asset of the company culture, since it is above the behaviour of the company members.
- Explicit knowledge is estimated to be only about 20% of the total amount of knowledge in a company. The remaining is tacit knowledge, which is normally shared only for a small amount. One of the important challenges of KM is to provide tools to share the tacit knowledge, which is a personal asset of the human beings in a company

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## Collect and share knowledge

- Explicit knowledge can be managed inside an Information and Communication Technology (ICT) system.
- To manage tacit knowledge, people must communicate: informal and individual networks connecting people, helping to solve the daily problems
- Unfortunately, often no track record remains of such knowledge exchanges (typically, they happen verbally and/or by phone, without recording)
- There is a need of organizing the knowledge. There is a need for places where

tacit knowledge can become esplicit

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## KM Systems

- Knowledge Management systems are aimed at facilitating and speeding up the sharing of best practices, lessons learned, and other know how inside the organizations
- The above systems are based on ICT tools (portals, data bases, research engines) to organize and present explicit knowledge
- Virtual Communities help to
- Virtual Communities are groups of people who interact using information tools (e-mail, chat, video conferences and so on) having a possibility to record and retrace the contacts; they help building relationships between people and sharing esplicit knowledge

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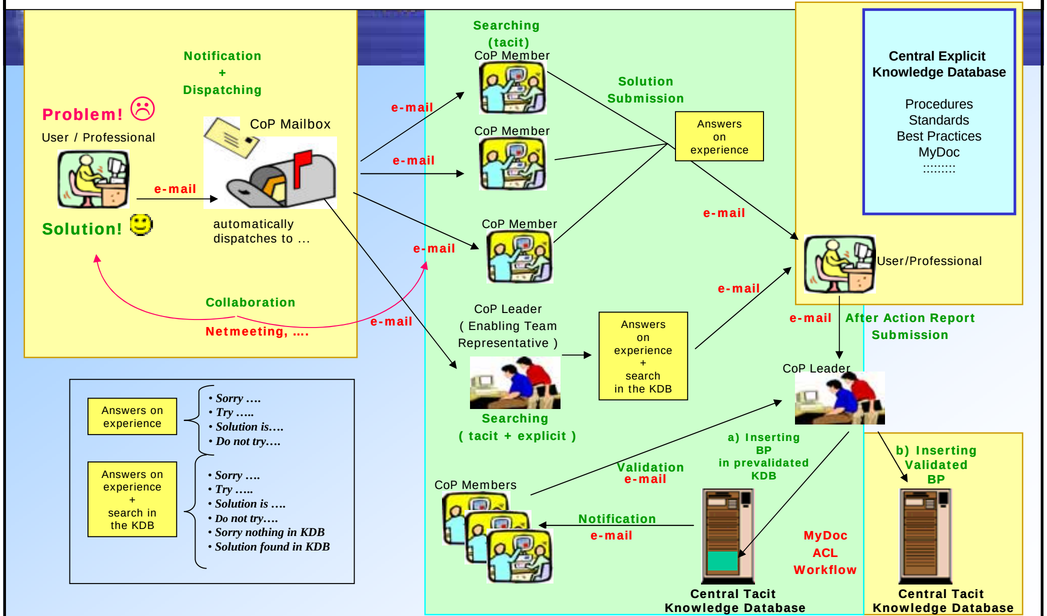
# Communities of practice

- Communities of Practice (CoP) are virtual communities made up of people who share a passion for something that they know how to do and who interact regularly to learn how to do it better
- Communities facilitate and speed-up the sharing of best practices, lessons learned and other 'know how' across the organisation



## Workflow for a Problem Solving Community

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## WHY A MATERIALS CoP?

The importance of being a “User” of materials - mainly of structural materials – is nowadays growing in the industry

In Eni Group, competencies on materials are widespread and transversal

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## FACTORS OF IMPORTANCE

- Increasing severity of the environment for new installations (deep water, permafrost…)
- Increasing aggressiveness of crude oil(water cut, sulphur content)
- Increasing age of plants and components
- Strategic importance of operating plants worldwide
- New aptitude – especially in Europe and US – toward the responsibility of Users in Health, Safety and Environmental issues

Experience and knowledge in the field of Materials are necessary to support decision

- Design
- Inspection
- Maintenance
- problem shooting
- fitness for service…

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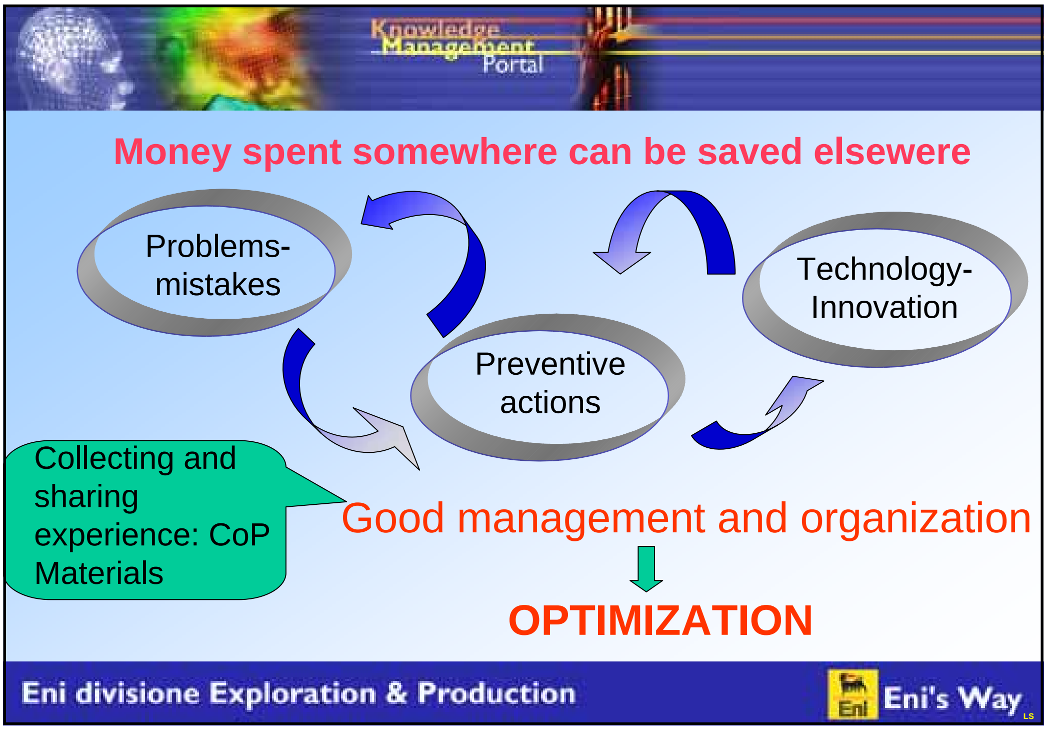
Knowledge Management Portal
Money spent somewhere can be saved elsewere
Problems-mistakes
Technology-Innovation
Preventive actions
Collecting and sharing experience: CoP Materials
Good management and organization
OPTIMIZATION
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Knowledge Management Portal
BIP
Members of the Materials Cop have an experience in:
Materials properties
Inspection and control
Risk assessment
Damage mechanisms and their prevention
Corrosion Management
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## Mission of the CoP "Materials"

- Promote and support development and diffusion of knowledge in the field of structural integrity of materials for oil & gas industrial plants
- Realize a survey of needs and resources inside the Group
- Implement and share the Group experience Data base

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## CoP boundaries

- **Domain***:* the definition of the area of shared inquiry and of the key issues
- **Community**: the relationships among members and the sense of belonging
- **Practice**: the body of knowledge, methods, stories, cases, tools, and documents

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# A space for a CoP

Space for meetings (physical)

Space for relationship → portal, mail
(*interaction, emotion, thinking*)

Tacit Space → ideas, proposals
(*creativity, proactivity, energy*)

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# CoPs and scientific associations

- Can a scientific association be a CoP?
- Small groups of specialists (named Technical Committees, Working Parties or the-like..) who meet regularly and organize events
- Web site and communication via mail

EXAMPLE

- The European Federation of Corrosion is organized in Technical Committees (TCs)
- Each of these TCs focuses on selected aspects of corrosion and attracts experts from all over the world

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## The role of associations

- Associations and TCs can act as a Knowledge Management System with the objective of facilitating and speeding-up the sharing of best practices, lessons learned and other 'know how' across the scientific community



Knowledge Management Portal

## FUTURE WORK

- The contribution to a KM system by a TC such as Refinery corrosion group could be:
- Realizing a survey of needs and resources;
- Preparing, implementing and sharing an experience Data Base
- Support the creation and successful life of the international network.

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Eni's Way

## CONCLUSIONS

- The Management of Knowledge and the solution of complex technical problems in a global world is an important challenge for the future. The contribution of existing networks such as technical associations and Working Parties (Communities of Practice) is very important to enhance the cooperation between scientists and experts all over the world

# Appendix 8

# Cases of failure analysis in industrial plants

**Sergio Volontè  (Tecnimont)**

## Case of failure analyses in industrial plants

TECNIMONT

HEAT EXCHANGER KETTLE TYPE: CORROSION OF THE TUBE BUNDLE


Author
dr. Sergio Maria Volonté
Corrosion & Painting
Group Leader


## Case of failure analyses in industrial plants

TECNIMONT

- ITEM: KETTLE USED AS EVAPORATOR
- FLUID

  SHELL SIDE: WATER SOLUTION OF POTASSIUM CARBONATE in 3.6% (pH = 8.3) → out 18.1% (pH = 10.7)

  TUBE SIDE: PROCESS GAS
- OPERATING CONDITIONS

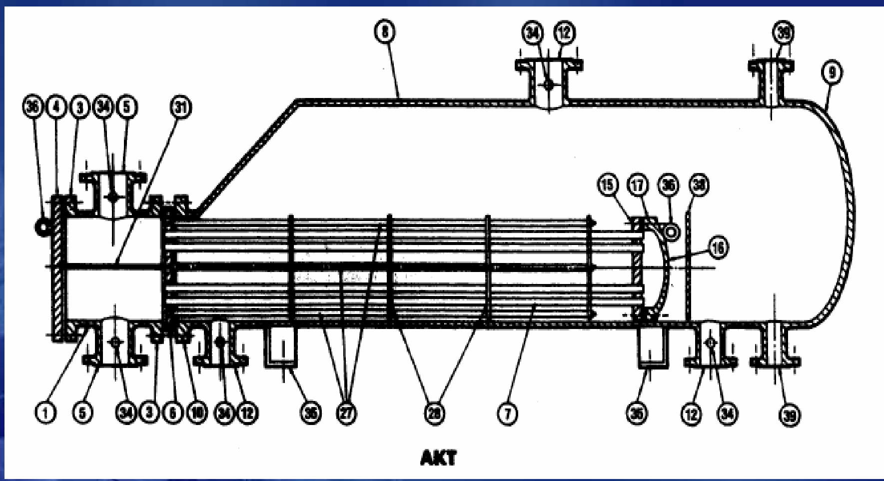
  TEMPERATURE (PRESSURE) SHELL SIDE: 145 °C (5.3 bar g)

  TEMPERATURE (PRESSURE) TUBE SIDE: in 250 ÷ out 156 °C (32 bar g)
- MATERIAL OF CONSTRUCTION: STAINLESS STEEL UNS S30400
- TUBE - TUBE SHEET JOINT: STRENGTH WELDING PARTIALLY MECHANICAL EXPANDED WITHOUT GROOVES
- FAILURE PLACE: FREE SURFACE LOCALIZED BETWEEN THE TUBE AND THE TUBE SHEET, SHELL SIDE
- SERVICE LIFE BEFORE FAILURE: 2 MONTHS

## Case of failure analyses in industrial plants

TECNIMONT

KETTLE: GENERAL SKETCH

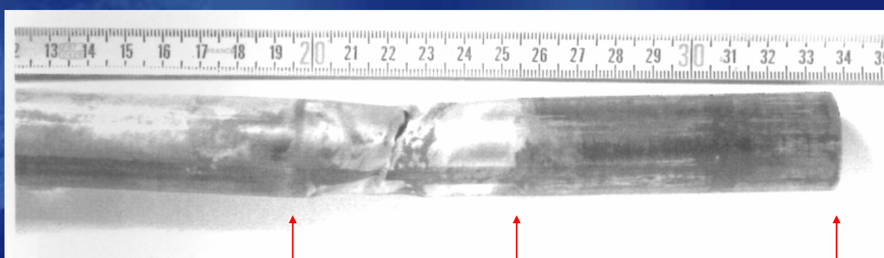



## Case of failure analyses in industrial plants

TECNIMONT

THE TUBE SURFACE UNDER THE TUBE-SHEET WAS FOUND:

- PART OF THE TUBE MECHANICALLY EXPANDED (ABOUT 60 mm): BRIGHT AND THE THICKNESS EXTREMELY THIN.
- PART OF THE TUBE NOT MECHANICALLY EXPANDED (ABOUT 80 mm): MATT AND FREE FROM CORROSION.

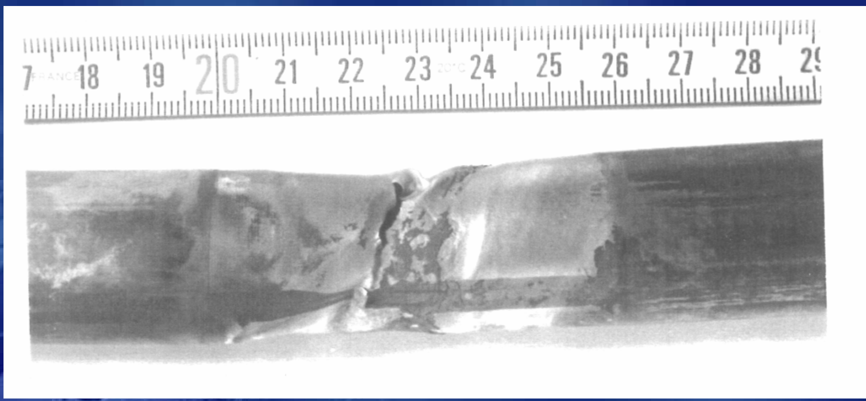


SURFACE NOT MECHANICALLY EXPANDED

SURFACE MECHANICALLY EXPANDED

## Case of failure analyses in industrial plants

DETAIL OF THE PREVIOUS PHOTO: THE BREAKING HAPPENED DURING THE REMOVING OF THE TUBE FROM TUBE-SHEET: THE THICKNESS WAS TOO LOW.



## Case of failure analyses in industrial plants

- TESTS AND RESULTS CARRIED OUT IN THE LAB:

  CHEMICAL ANALYSIS OF THE MATERIAL OF CONSTRUCTION: CONFIRMED THAT WAS UNS S30400

  METALLOGRAPHIC EXAMINATION: CONFIRMED THAT:

  - THE MATERIAL USED FOR CONSTRUCTION WAS PLACE IN SERVICE SOLUTION ANNEALED
  - THE SURFACE INTERESTED BY CORROSION SHOWED A “WAVED” PROFILE, FREE FROM LOCALIZED CORROSION (PITS AND INTERCRYSTALLINE CORROSION)

  CHEMICAL ANALYSIS OF THE $K_2CO_3$: THE CONTENT OF CHLORIDES IN THE CONCENTRATED SOLUTION WAS LESS THAN 100 ppm, VALUE CONSIDERED “NEGLEGIBLE” IN ALKALINE SOLUTION

## Case of failure analyses in industrial plants

TECNIMONT

- USEFUL INFORMATION

  THE AQUEOUS SOLUTIONS OF POTASSIUM CARBONATE, WHEN OVERHEATED, ARE SUBJECTED TO HYDROLISIS PRODUCING POTASSIUM HYDROXIDE AND CARBON DIOXIDE.

  THE CHEMICAL REACTION IS THE FOLLOWING:

$$K_2CO_3 + H_2O \rightarrow 2\ KOH + CO_2$$

THE NEXT TABLE, ONLY AS EXAMPLE, SHOWS THE RATE OF DECOMPOSITION OF AN AQUEOUS SOLUTION 0.2N OF $K_2CO_3$ BOILED UNDER REFLUX AT ATMOSPHERIC PRESSURE.

## Case of failure analyses in industrial plants

TECNIMONT

Aqueous solutions of potassium carbonate are slowly decomposed on boiling. For example, a 0·2N. solution boiled under reflux for 5–7 days in a current of air or steam (to remove carbon dioxide as formed) showed 65% decomposition. The extent of decomposition is stated to be proportional to the square root of the time of boiling, as the following Table shows.[184]

TABLE XX. - DECOMPOSITION OF POTASSIUM CARBONATE (0·2N.) SOLUTION ON BOILING UNDER REFLUX

| Time, mins. | $CO_2$ elimin'd g. | $CO_2$ elimin'd % | K(%decomp./mins.$^{1/2}$) |
|---|---|---|---|
| 80 | 0·0126 | 7·16 | 0·801 |
| 330 | 0·0336 | 14·9 | 0·82 |
| 900 | 0·0562 | 25·4 | 0·846 |
| 1355 | 0·0718 | 32·9 | 0·89 |
| 1620 | 0·0778 | 35·2 | 0·875 |
| 2380 | 0·0912 | 41·2 | 0·845 |
| 3050 | 0·1008 | 48·75 | 0·88 |
| 3810 | 0·1096 | 49·5 | 0·802 |
| 5250 | 0·1184 | 53·45 | 0·738 |
| 5960 | 0·1247 | 56·3 | 0·73 |
| 6675 | 0·1315 | 59·4 | 0·72 |
| 7380 | 0·1375 | 62·1 | 0·73 |
| 8180 | 0·1433 | 64·7 | 0·715 |

$K_2CO_3$ 0.2N CORRESPONDS TO 2% w/w, THIS VALUE OF CONCENTRATION IS COMPARABLE TO THE KETTLE FEED AQUEOUS SOLUTION

8180 minute CORRESPOND TO LESS THAN 6 DAYS

FROM: MELLOR'S – COMPREHENSIVE TREATISE ON INORGANIC AND THEORETICAL CHEMISTRY – VOL. II – SUPPLEMENT 3 – 1963 - LONGMANS

## Case of failure analyses in industrial plants

TECNIMONT

- CAUSE OF THE FAILURE

  THE CORROSION PRIMED ON THE TUBE SURFACE HAS BEEN ATTRIBUITED TO THE WRONG MECHANICAL DESIGN WITH THE FORMATION OF A CREVICE BETWEEN THE TUBE AND TUBE-SHEET.

  THE HYDROLYSIS OF THE $K_2CO_3$ WITH THE PRODUCTION OF A STRONG ALKALI SUCH AS KOH IS ONLY A CONSEQUENCE OF A WRONG DESIGN OF THE EQUIPMENT.

  IN FACT, INSIDE THE CREVICE THE FOLLOWING HAPPENDED:

  - HIGH EVAPORATION OF THE WATER THAT INCREASE THE ALKALI CONCENTRATION;
  - LOW REDUCTION OF THE WALL TEMPERATURE DUE TO THE LITTLE VOLUME OF THE AQUEOUS SOLUTION.

  THE MATERIAL OF CONSTRUCTION: UNS S30400, IS CHARACTERIZED BY ACTIVE / PASSIVE BEHAVIOUR.

  FROM LITERATURE, AT TEMPERATURE HIGHER THAN 150 °C, CONCENTRATED SOLUTIONS OF KOH CAUSE HIGH CORROSION RATE OF UNS S30400 (ACTIVE BEHAVIOUR).

## Case of failure analyses in industrial plants

TECNIMONT

- ADOPTED SOLUTIONS

1. EXTENSION OF THE MECHANICAL EXPANSION OF THE TUBE FOR ALL THE THICKNESS OF THE TUBE SHEET. THIS MODIFICATION HAS AVOIDED THE PRESENCE OF THE CREVICE.
2. INSERTION OF FERRULES INSIDE THE TUBES FOR REDUCING THE THERMAL CONDUCTIVITY IN CORRESPONDANCE OF THE TUBE SHEET.

- FEED-BACK FROM FIELD

  THE HEAT EXCHANGER HAS BEEN IN OPERATION FOR AT LEAST TWO YEARS (PERIOD WHICH TECNIMONT HAS PROVIDED ASSISTANCE TO CLIENT) WITHOUT ANY FAILURE.

## Case of failure analyses in industrial plants

TECNIMONT

- OTHERS POSSIBLE SOLUTIONS SUCH AS:

1. JOINT TUBE SHEET - TUBE BY BORE-WELDING (THAT IS A BUTT WELDING BETWEEN THE TUBE SHEET AND THE TUBE);
2. CHANGE OF THE MATERIAL OF CONSTRUCTION TO NICHEL OR ITS ALLOYS;

HAVE BEEN CONSIDERED TOO MUCH EXPENSIVE FOR THE SERVICE.

- FINAL CONSIDERATIONS

THE INSERTION OF THE FERRULES AND THE EXTESION OF THE MECHANICAL EXPANSION HAVE SOLVED DEFINETELY THE ORIGIN OF THE FAILURE.