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20 YEARS ON LESSONS LEARNED FROM PIPER ALPHA
THE EVOLUTION OF CONCURRENT & INHERENTLY SAFE DESIGN

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Prompted by 20th Anniversary of Piper Alpha accident-
The worst tragedy in offshore history.

Aftermath Lord Cullen Report (Govt Inquiry), led to major changes in Regulations. Transition from ‘Prescriptive to Goal Setting’ and the Safety Case.

Much written but with passage of time, given more tempered look at Integrity Management (IM).

Interpret need for more reliable material selection & corrosion analysis as strong precursor to effective IM. (Written paper presents arguments in greater depth)

CAVEAT
The paper and talk reflect the opinions of the author(s) only, and not necessarily of the companies.
Piper Alpha - Before and After.
A Compelling DVD is available on request.
BACKGROUND

Piper Alpha disaster 6th July 1988, a monumental event on par with JFK assassination, 9/11, UK 7/7, etc. (people remembered where they were, & industry very badly shaken) 167 died, 62 survivors.

Media frenzy of the day: root causes were variously reported over the first year as: metal fatigue, poor maintenance, inadequate operating procedures, bad work practices, human error, etc.

News coverage was almost exclusively Piper related, and once the inquiry started, often steady stream of witnesses, van loads documentation etc often seen to/from the court houses. (Q- Contrasting arguments re- more or less documentation).

SOME FACTS:

- Piper Alpha (Occidental) commissioned ca 1976:
  - One of largest in NS, prolific producer heyday >317,000 bopd
  - History of modifications (oil/gas) ‘plagued’ with corrosion issues (‘root events’)
  - Replaced w/Piper Bravo~120m fr. original site 1993 (Occidental>Talisman)
  - Ramifications: Occidental found guilty, fined, left the North Sea.
  - No criminal charges filed.
  - No ‘class action’ –individual cases still ongoing.

- 5th most expensive accident ($3.4b), Challenger 1986 ($5.5b), Prestige oil tanker 2002 ($12b), Colombia 2003 ($13b), Chernobyl Reactor 1986 ($200b).
LORD CULLEN FINDINGS


THE MOST DAMNING CONCLUSIONS WERE:
Poor plant design, (incl. modifications).
Breakdown of the permit to work (p.t.w.) system.
Bad maintenance management.
Inadequate safety auditing, and training.
Poor communications (all levels).
Poor emergency management (incl. w.r.t nearby platforms).
Lord Cullen made >106 Recommendations.

POST PIPER OBSERVATIONS
Lack of foresight, in-depth analysis, poor management.
Role of latent degradation/corrosion mechanisms.
Must agree that Corrosion is a hazard
Need: Mandatory ethics training, Co-ord global Regs, Prof. licensure?
Conflicts of interest? Ongoing CAPEX/OPEX debate? etc.

Cullen report gave a vital springboard for evolution of critical concepts:
Corrosion Management, Inspection Management, Asset Integrity Management, IM, & Knowledge Management, largely via UMIST/RGIT.
(Key Architects: Drs Dawson, Thompson, Kirkwood, Cox, Prodger, et al)
‘SWISS CHEESE ANALOGY’
aka: Jigsaw effect, chain of events, perfect storm, Murphy’s law, etc.

James Reason 1990 theorized: Hazards (often latent events) align and losses (consequences) accumulate.

Often see with Hindsight (20/20) how intervention could save the day. Thus predictive reasoning/forecasting is plausible.
VIMP: These events are not ‘one off’ - Can and Are Repeated.
USA Equivalent Regulation Changer Aug 2000 - Carlsbad NM.
Evolution of Onshore/Offshore DOT/MMS/Federal Regs CFR -192/195/250 etc.
Forensics revealed critical role of water/chlorides/MIC/H₂S/CO₂
Noticeable: Differentiate Major asset ‘entity ‘threats, and Scenario (2nd Tier/Secondary) effects.

2ND TIER EFFECTS - ROLE OF CORROSION
INDUSTRY-DRIVEN DEVELOPMENT

Upstream Sector

Internal Corrosion
51%

External Corrosion
15%

Oil and Gas Pipeline Failures by Year --
Typical Industry Sector Performance

AEUB, Canada 1998

Position considered unchanged ca 2008

Corrosion often the latent culprit (> 10 Mechanisms).
Canadian, Russian, Norwegian studies 1998/2009 Correlation Pipeline Defects.
Reveal Internal Corrosion > 51 % failures.
HOW TO ADDRESS?
TWO SCHOOLS OF THOUGHT
Effectively two powerful viewpoints, invariably at loggerheads, heavily influenced by project economic constraints rather than Integrity Management.
KEY DEBATE IS VERY PARTISAN

- **Materials Selection and Corrosion control for Fabrication** ('Just build it’ Lobby).
  Driven by PM` s/Account leaders
  Basic Idea - pass on the problem to OPEX.
  
  **Versus**
  
- **Materials Selection for Life Cycle Performance.**
  ('Pay now or pay more later’ Lobby).
  Driven by SME` s ( operator and contractor)
  predictable issues but argument is a tough sell.
Evolved Best Practice- Offshore/Subsea Concurrent Design

FEED: Front End Engineering Design.

Phase 1
Concept
$/Regs
*

Phase 2
Pre-FEED
$/Regs
**

Phase 3
FEED
$/Regs
***

Phase 4
Execute
$/Regs
****

Phase 5
Operate
$/Regs
*****

*Materials/Corrosion Effort and ‘MOC’ increased as criteria/new data accrued. Methodology Probably first applied in Nuclear Industry.

AKA: Appraise, Select, Define, Execute (ASDE), etc

Redefines: ALARP and ISD: Simplifying Attitude
ALARP RISK TRIANGLE
Risk ‘As Low As Reasonably Practical’
Contrast to the powerful ROI motivation

Key Phrases in ISD: Attitude, simplify, less moving parts, location-location, challenge-challenge, thus SME`s, prevention> protection/cure, thus CRA’s/CA, etc,
Case Histories: Advances fire/blast walls, repeat Piper event very unlikely.
But advised~10 piper type leaks/yr. Case Histories reveal such potential.
FLOWLINE EROSION-CORROSION FAILURES
Applicable to: pipelines, flowlines, piping, tubing, etc.

Weldment

Acid clean scales

Steady State Filming

Foreign Blockage

Convergence critical parameters

FLOW

Unsteady Flow Zone

Entry Length
CHOKE ASSEMBLY:
Catastrophic mixed erosion/cavitation failure.
Danger broken parts in system!
(Tungsten Carbide & 410 SS sleeves)

Dimpling at leading edge of erosive wear front

Major flow excursions Note-clean zero corrosion products. Differentiate~Erosion/Impingement/Cavitation
DANGEROUS EMBRITTLEMENT PHENOMENA-HIC, HE, (SCC, SSC, etc)
SAFETY IMPACT/PRODUCTION STOPPING BALLAST TANK COATING FAILURES (Alkalinity pH >10)

Gray Primer

Internal repair coatings per ISIP

TOPSIDES UNDER SUPPORT CREVICE CORROSION:
(Note: Quite similar to CUI) - Both Safety Critical!

Costly Retrofits : Need timely creative solutions
‘Crevice Free’ curved I-Rod designs.
INSIDIOUS SWEET CORROSION: CO₂, low PH < 4.5

Most dangerous mechanisms: Aggressive combos: Cl⁻, CO₂, H₂S, MIC, Pitting, Crevice, etc. Susceptible Features: Welds, flanges, fasteners, etc. Prediction a challenge: No COP-Thus JIP’s (Ohio, Tulsa, Univ’s)
COLD DEEP SUBSEA PIPELINE & RISER INADEQUATE CP DESIGN
Very Costly Retrofits

LHS: Over Active Anode    TSA Coating: Accelerated Attack
RARE - BUT CRITICAL CORROSION INSIDE PRESSURIZED AIR BOTTLE.
FAILURE PREDICTION: MAJOR ‘ACHILLES HEEL’
(PER MATERIALS AND CORROSION ISSUES)

• Hypothesis: Materials/Corrosion - critical role all failures.
• Ext. Corrosion: Design to CP standards ok (ISO/NACE/DNV etc.)
• Internal Corrosion: Problem mismatch theory, modeling, lab, field, etc. Dangers of non-representative conditions.
• No reliability reproducing unsteady, or transient conditions.
• Ltd confidence w/multiple variables, CL-, CO₂, H₂S, MIC, etc.
• Need tackle synergistic localized corrosion and erosion.
• Uncertainties re- water wetting propensity, and sites thereof.
• Dead leg corrosion- stagnant pocket corrosion major issues.
• Specific pre-corrosion, BOL, and TOL issues.
• Important to brain storm ‘what if’ scenarios

PS: Good News - JIP’s looking into most of these areas
### MAJOR FACET - COMPLEXITY OF FLOW REGIMES

**Q’s:** Steady Or Unsteady? Water/Oil Wetting? Corrosion Responses? Cocktailing Inhibitors? Impact on Production/$$ Critical?

<table>
<thead>
<tr>
<th>Flow Regimes (Horizontal Flow)</th>
<th>Flow Patterns In Vertical Upward Flow</th>
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<tbody>
<tr>
<td>Fully Dispersed Homogenous</td>
<td>Bubbly Flow</td>
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<tr>
<td>Dispersed Bubble</td>
<td>Slug Flow</td>
</tr>
<tr>
<td>Smooth / Stratified (Segregated or Mixed)</td>
<td>Churn Flow</td>
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<tr>
<td>Slug (Intermittent)</td>
<td>Annular Flow</td>
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<tr>
<td>Stratified Wavy</td>
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<tr>
<td>Annular Dispersed</td>
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RISK BASED CORROSION ASSESSMENTS
RISK FACTORED CORROSION ALLOWANCES

(2 methods: additive, synergistic (factorization, etc)

1/ \[ CR_{tot} \approx Uniform \, CR + Erosion \, Rate + Other \, physical \, degradation \, rates(impingement/cavitation/wear \, etc) \]

Note: Can use 0.1, 0.05, 0.025 mm/y as data dictate.
Then total CA derive/reconcile for the Life Cycle
NB: Select worst case of 5-20 scenario, can be overtly conservative

2/ \[ CR_{tot} \approx \Phi(P,T,V,CO_2 \, etc) \times F_{flow} \cdot F_{exc} \cdot F_{ff} \cdot F_{mic} \cdot F_{film}, \, etc. \]

Factors ALARP risk -appropriate for synergistic behavior.
Based on HML concepts, and defensible. Pragmatism forces
selection of “Pessimistic, Median, or Optimistic” correction
factors typically in range 1.025 to 1.5

Challenging Q’s :
Use worst case, or safe design- How assess mixed variables (separately or clumped).
Average conditions (PTV), max, or design, conditions? Line corrosion profiles?
Incl. pseudo corrosion allowances? Use CA or MAWT as cutoff? Care over conservatism
PREMISE: Industry wary of over conservatism. But must Articulate Risk Identification, Risk Analysis, Risk Management, vs Confidence/Costs. Thus ALARP/Inherently Safe(r) Designs

Political risk, HSE risk, Economic Risk, Engineering Risk

Quantify Corrosion Risk - Decision Matrix
Interpret Risk as ~ Probability Failure x Consequence
POSITIVES FROM PIPER ‘A’ EXPERIENCE


- Brain storming ‘what if’ scenario analyses- Changes in Regs, improved best practices, beware confluence of dangerous variables, learning's incl from near misses. Need approve all design changes/mods, invoked principles of MOC.

- Risk based life cycle analyses; independence avoid ‘group think’. Integrated modeling: mechanistic, probabilistic, empirical, deterministic, heuristic; etc.

- Gaps in data resolved via risk and case histories, evolution of focused JIP’s and non-standard R&D. Stimulus for Global IM Regulations.

- JIP’s big plus, bridging gap b/w Academia & Industry & thus b/w fundamental and applied research (Ohio/Tulsa) also encouraged private initiatives: T4B’s.

- Development of Key Performance Indicators (KPI’s) – and role of Key Failure Indicators (KFI’s) rather than difficult root causes. Solid way forward.

- Confirmed best results if multi-disciplined teams understand and implement lessons learned. Existing Challenges : balance of legal and commercial.

- Provoked concepts: Conservatism, Pragmatism, ALARP & ISD (mandatory) May stimulate step changes academia/JIP led modules in engineering ISD?
**STILL CRITICAL QUESTIONS & QUERIES**

- Are Regulations at appropriate level to help creativity/advanced solutions? UK: Possibly over -documentation high. USA: Possibly under, docm’n lower.

- Can the ‘Swiss Cheese’ or ‘Jigsaw Effect’ be broken by anticipation, prediction, and planned intervention? - *Can break the chain- Big Yes!*

- Risk based solutions bridge the knowledge gaps- 80/20 Pareto Principles? Focus maintenance/inspection when needed not when scheduled? Compare Aero/military? Pay attention to all sources even the voice of inexperience!

- Are levels of education, job training, experience, about right or be improved? Failures repeated w/20-30, OR 5 yr career cycles- clash of ideals young/old?

- Role of Standards/Rules, etc - sometimes out of step w/Industry experience? Must go beyond the code -think Life Cycle- ‘gaming the system’ not on!

- Are the levels of expertise available about right? Will global technology transfers ‘cross asset learning's’ i.e. KM help?

- Can standardization of designs and equipment help IM? Jury still out.

- **Solutions Needed!** Challenging deepwater/arctic designs- Thrust to Inherently Safe designs. Reflect ‘Change in Attitude’ rather than methodology (Cullen, Dalzell, Poblete, et al).
STRONGLY RECOMMEND ‘ADDED VALUE’ OF INHERENTLY SAFE DESIGN (ISD) AND ‘ALARP’ PROCEDURES - THRU THE LIFE CYCLE.

Target: Fit for Purpose Designs and Fit for purpose Solutions
Fundamental Argument: Risk Levels = Material Choices, Quantify via KPI-KFI.
Knowledge Management: ‘Safe Life/Fail Safe’ ideas, best advances in technology (Focus - instrumented corrosion spools-FSM/RPCM, Guided Wave UT, etc)
NEAR TERM RECOMMENDATIONS

3/ More focus on latent Corrosion - does not recognize borders.
5/ Avoid conflicts of interest – DOE/HSE separation roles/responsibilities good- consider per GOM?
6/ Powerful GOM concept PINC’s consider per North Sea?
7/ Facilitate industry failures data base – Report all failures and ‘near misses’ to enhance lessons learned.
8/ Need multi-disciplined verification and validation of designs. Ongoing development of relevant and pragmatic KPI’s
9/ Reconcile CAPEX/OPEX. Stir the debate to conclusion.
10/ Promote JIP formula (Univ./Industry) –Champion ISD in Univ. curricula looks best way forward.
IMMEDIACY OF ‘NOW’ DEEPWATER DRIVEN

Centerline proactive approach eliminates costly corrective actions (Invariably, MOC, re-design, excursions, labor/installation, KPI’s )
In the context of Inherently Safe and Inherently Reliable designs.

Good Business means managing and balancing risks
LONGER TERM RECOMMENDATIONS

Better Cooperation between Engineering Societies
Likewise Regulators: NS/GOM/AUS, etc... Options MOU?
Paradigm shift thinking - esp. via new generation of engineers.
Plausible engineering version of ‘Sarbanes Oxley’ in future?
Transformation of engineering discipline to a ‘vocation’
Akin to the medical field - Licensing Debate.

Re-define Roles & Responsibilities for Engineering Managers.
Many Co`s bringing in formal HSE, LOPA & ISD guidance procedures.

Encourage contractor vested interests & eliminate ‘NRB’ factor
Better Survivability Training - ‘hysterical strength’ (33 to 100%)

Offshore/Marine to gravitate towards practices as utilized by
Aeronautical, Nuclear, DOD, etc. Role of new initiatives such as PAS55

Better Technology Transfer as driven by the Global market Place.
More Engineers into business decision track roles, etc.
THANK YOU!

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