Cathodic Protection and Pipeline Integrity Course for SGN Managers Introduction

By

[redacted]

IACS Limited

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Contents

- Just going to run through some of the basics on what CP is and how it works.
- Give information on design code requirements and relevant standards
- Provide a little bit of practical guidance
- Describe CP systems and the maintenance strategy
- Give information on HSE intervention topics and legislation
- Identify gaps and deficiencies in SGN management of pipeline corrosion and improvements that can be made and discuss a typical SGN TD 1 Affirmation
- Cover over the line CP surveys and requirements
- Give a few case histories of where things have not gone according to plan

- **YOU CAN TAKE NOTES IF YOU WANT BUT I WILL GIVE A COPY OF THESE SLIDES TO YOU AFTERWARDS WITH A CERTIFICATE**

Course Content Timescale

Time	Content
09.00 to 09.15	Brief introduction to course.
09.15 to 10.30	Introduction to pipelines, examples of pipeline failures, pipeline failure modes, frequencies and information.
Break	
11.00 to 12.15	Discuss onshore CP systems and requirements for CP monitoring and cover basis CP monitoring techniques e.g pipe to soil potential measurements monitoring frequency, legislation and standards
Lunch	
12.45 -14.30	Give details of pipeline CP system materials
Break	
15.00 to 16.30	Over the line surveys

Course Content Timescale	
Time	**Content**
09.00 to 10.30	DC stray current interference
Break	
11.00 to 12.15	AC interference and electrical hazards
Lunch	
12.45 -14.30	Pipeline awareness and corrosion issues
Break	
15.00 to 16.30	Case studies and SGN corrosion management and discussion

Standards

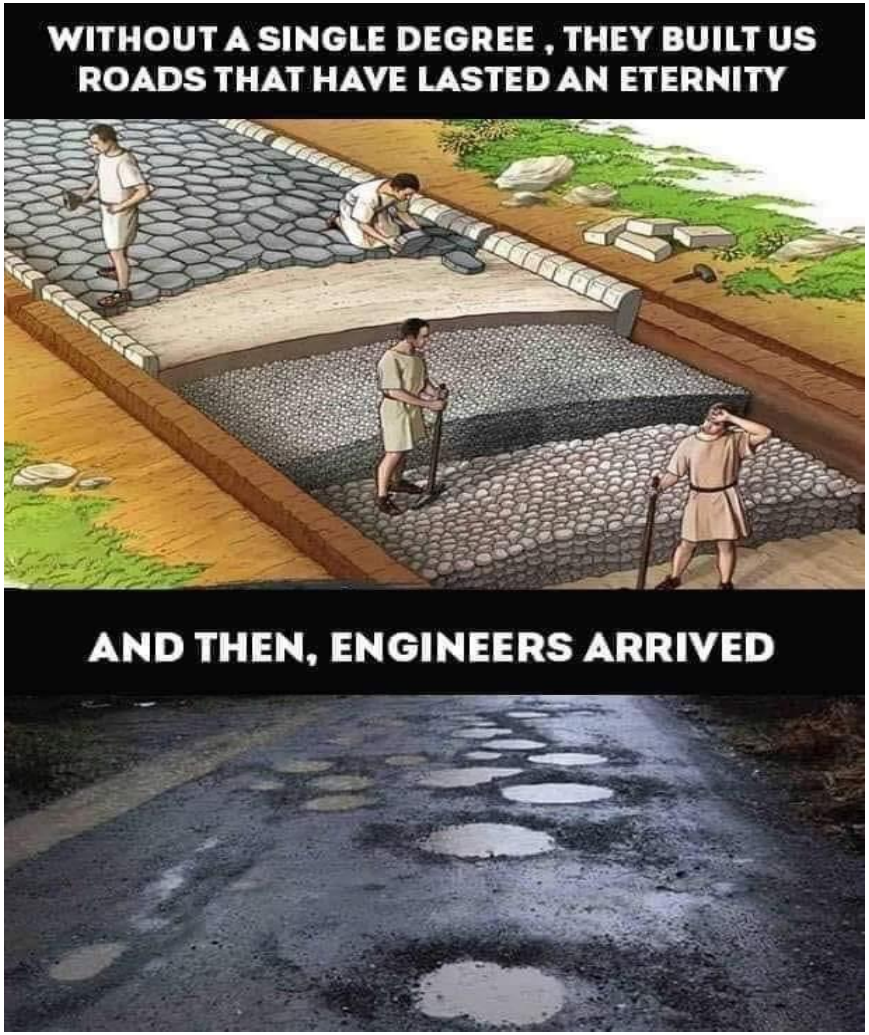
- The primary CP standard is SGN/PM/ECP/2
- There are various IGEM and BS EN ISO standards as well that apply to CP and you should be aware of these
- SGN must ensure that it complies with BS/EN standards and its own policies
- I will give a list of standards in the subsequent slides.
- My experience is that SGN don't always comply at present with its own policies and certain aspects of BS EN standards and this has been the case for a number of years

Standards

- IGEM/TD/1 is the design standard for pipelines above 7 barg and that gives quite good guidance on corrosion management
- IGEM/TD/3 is the design standard for below 7 barg lines and its guidance on corrosion management and CP is pretty poor in my opinion and the latest Edition does not contain appropriate guidance.
- Best to follow SGN standards

Standards and Changes over Time

- The older standards had a lot of good guidance, and we seem to have forgotten that.
- When standards are updated, we should ensure that guidance where useful and practical is still included



GIS, IDN and Other Operators

- SGN just has SGN/PM/ECP/2 but other operators have a number of other standards that they use for CP.
- National Gas has a good standard covering over the line survey procedures T/SP/ECP/8
- There are two new IDN standards soon IDN-ECP/5 – Management Procedure for AC Interference on Pipelines and GIS-ECP/6 - Work Instruction for Maintenance of AC Interference on Pipelines. I will discuss these
- SGN has a number of good work procedure documents, not sure when these were last updated but do you do need to give training in those. National Gas does have some good ones as well.

UK Gas Industry

- In the UK Gas Industry all operators should follow the same or similar standards, but they don't
- There is not even consistency in SGN . Southern Gas Networks do things differently to Scotland Gas Networks.
- In Scotland they have a dedicated gas pipeline team, but you don't in the South at the moment. You did in the past and that worked well

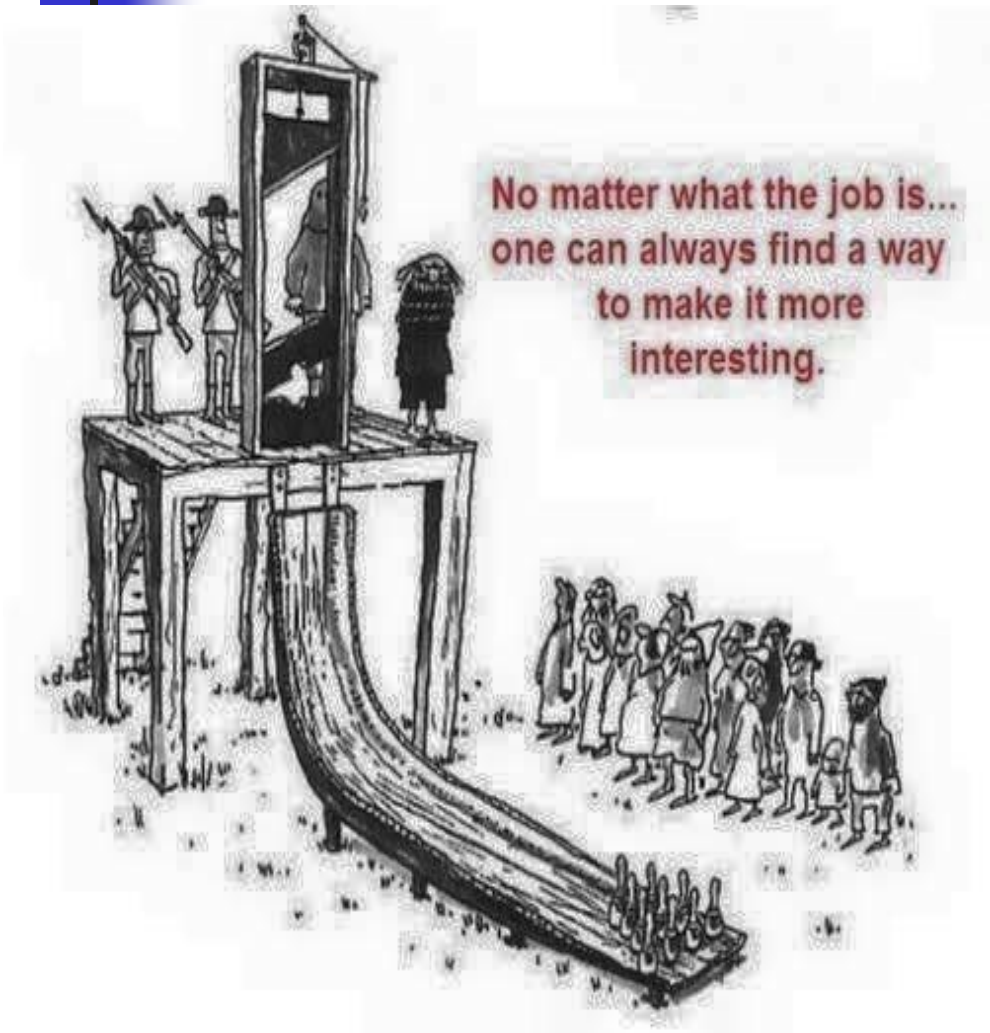
Examples of Non Compliance

- On of the main areas where SGN lack competency and do not undertake effect management of the risk is with DC stray current interference .
- I know the HSE are going to focus on that next year, and I am doing a training course for them later in the year on CP, corrosion plus AC and DC stray current.
- SGN is the gas pipeline operator with the highest level of DC stray current risk in the UK and your management of it from my involvement is not ideal.
- I will go through a few cases on stray current and hopefully give guidance on areas for improvement

CP and Corrosion

- National Gas has a dedicated team of corrosion engineers.
- SGN in the past used to have a CP section dealing with CP issues. I don't think you have that at the moment. SGN also had a pipelines section and does in Scotland but does not down south.
- Corrosion is now the main cause of failure in Europe on an aging asset, and SGN might need a dedicated resource to manage that.

Cathodic Protection and Corrosion



- Cathodic protection is not the most interesting subject.
- I have tried to put as many pictures in as I can to try and make it interesting
- Any questions please ask
- This course is designed to provide awareness and guidance and information on CP systems but also your pipeline management

Pipelines are Getting Old









Sissonville WV Natural Gas Pipeline Rupture



Alaskan Pipeline Failure 2003



Ltd.



Ltd.









Ltd.

Gas Pipeline Incident Belgium Third Party Damage







- Third party damage to the UK's major accident hazard pipeline (MAHP) networks by utility and construction contractors poses a serious risk to workers and the public.
- In July 2004, 25 people died and more than 150 were seriously injured in Ghislenghien, Belgium following construction damage to a high-pressure gas pipeline.
- MAHPs are usually buried less than 1.1 metres underground and can be identified by surface marker posts.
- Third Party damage is one of the main risk to cross country pipelines, but corrosion is also a primary failure mechanism.
- The HSE are concerned about how operators deal with minor damage to pipelines.
- Reduction in pipeline pressure before investigating unknown defects is recommended in P 11

T/PM/EM/76- Managing Releases

This table covers all pipelines.

Event	Pipeline Dia. mm (NB)	Maximum Thermal Hazard Range			
		0 – 19 barg	19 – 40 barg	40 – 75 barg	75 – 85 barg
0-25mm (0-1") leak	All	5	5	5	6
25-75mm (1"-3") leak	All	11	18	29	32
75-150mm (3"-6") leak	All	25	33	90	100
Rupture	168 (6")	25	55	140	151
Rupture	324 (12")	50	70	230	249
Rupture	457 (18")	72	90	290	312
Rupture	610 (24")	110	130	365	393
Rupture	762 (30")	133	190	455	482
Rupture	914 (36")	168	205	560	609
Rupture	1067 (42")	190	215	665	711
Rupture	1219 (48")	204	225	812	872

Note:- The above distances relate to distances at which individuals would be able to safely escape from the effects of the fire if the releasing gas ignited and as such they assume that individuals will be able to move away from the fire. They are not therefore distances away from any fire at which individuals would be able to safely stand for any significant length of time. For determining safe distances for setting up control points it is recommended that the above distances are doubled.

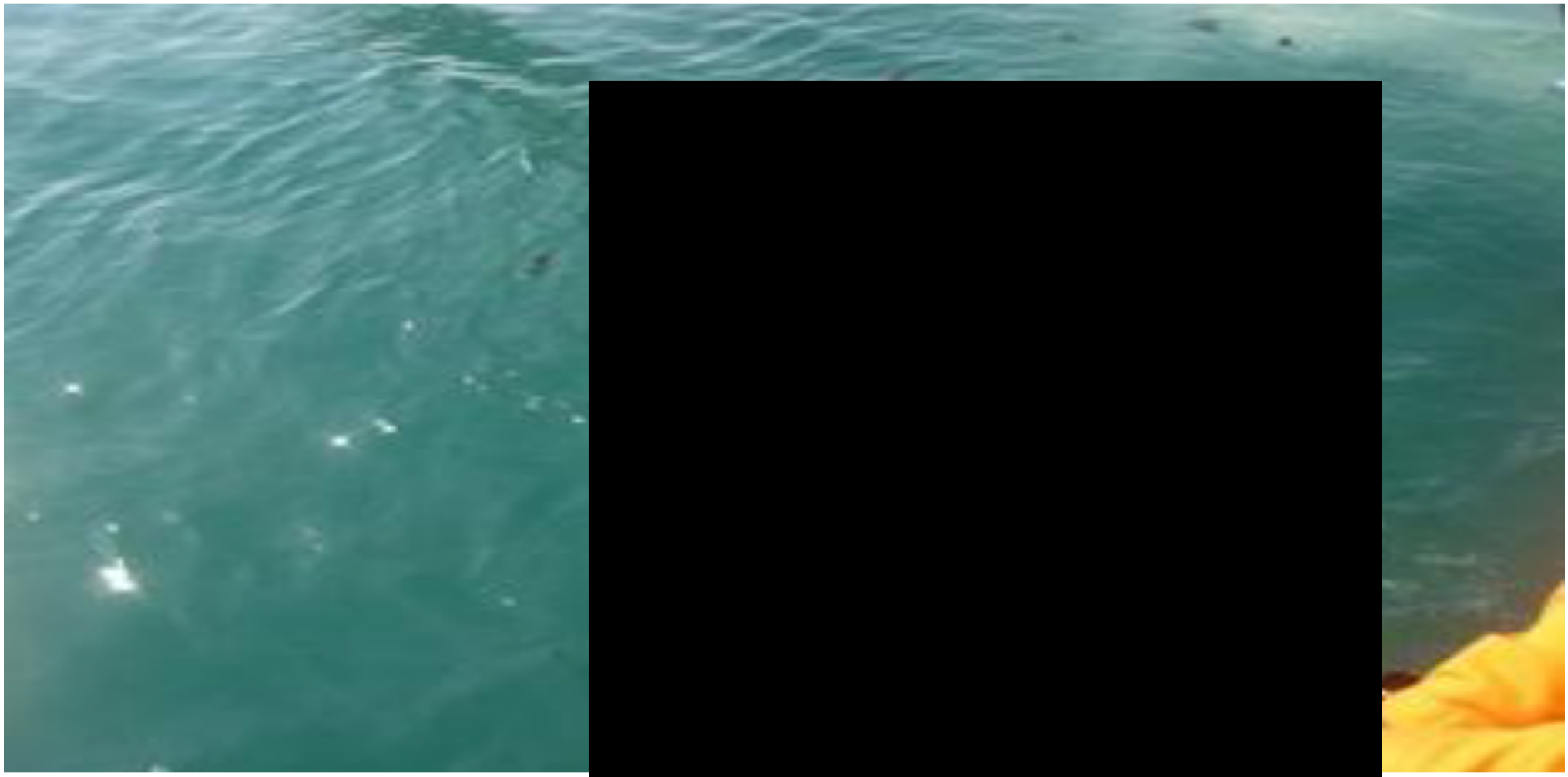
Now You See Me !



Now You Do Not



Hyundai installing a jacket offshore India, apparently someone forgot to allow for the weight of the piles in the mud mat design, the jacket broke through the sea bed which was very soft!



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Previous Slides

- These photos show planning is essential. Thus, although there is a Management of Change system that SGN employ it does not always mean that you will have a CP system that will work. Often CP is not considered as part of changes to designs.
- Managers won't be CP experts but if in doubt ask and make sure there is an awareness of it amongst distribution colleagues.

Internal and External Corrosion



METAL + WATER + CORRODENT = CORROSION

~~METAL~~ + WATER + CORRODENT = NO CORROSION

METAL + ~~WATER~~ + CORRODENT = NO CORROSION

METAL + WATER + ~~CORRODENT~~ = NO CORROSION

Are Pipelines different to any other high hazard industry?



Non pipeline accidents:

- **Bhopal, India** 02/12/1984 an uncontrolled release of gas resulted in 15,000 death and many more injuries. 30 years later still seeing birth defects.

- **The Banqiao Dam Collapse, China 08/08/75**

  Flooding caused Dam to collapse. Killing 230,000 people. Investigations reported that the dam was poorly engineered and constructed making it vulnerable. 1993 dam was rebuilt.



- **Exxon Valdez Oil Spill, Alaska** 24/03/1989

  Oil tanker hit Reef, near Alaska, spilling approx. 10m gallons of crude, killed 4 people, 250,000 seabirds, and 2800 sea otters.



- **Deep Water Horizon**, **USA** 20/04/2010 Eruption of gas caused an explosion, resulting in 11 deaths, and £18.7 Billion in fines. Causes by: (2 valve failures, dodgy cement, pressure test, leak not spotted, no gas alarm)





Nuclear accidents

- **Windscale** UK, October 1957 The Windscale plant consisted of two gas-cooled nuclear reactors. The accident started on October 8, 1957, when a routine heating of the No. 1 reactor's graphite control blocks got out of control, causing adjacent uranium cartridges to rupture. The uranium released began to oxidize, releasing radioactivity and causing a fire that burned for 16 hours before it was put out. The fire left about 10 tons of radioactive fuel melted in the reactor core.
- The radioactive contamination that escaped did wreak havoc. In the months after the Windscale Fire, a state of emergency was declared in the 500 km area around the plant. Livestock was quarantined; milk and dairy products were not considered safe.
- 33 known deaths and it is estimated to have caused 120 deaths due to cancer
- Clean-up took 10 years and cost at least $30 million, however its memory still remains and discoveries continue. Fallout measurements were reassessed in 2007, showing that the actual amount of contamination was at twice the level that it was previously thought to be.
- The UK government blamed the workers' incompetence for the disaster, rather than lack of efficient management or effective procedural policy. The latter reasons were later revealed to be primary factors in the incident.

Nuclear accidents



Chernobyl Ukraine, on 26 April1986 there was a catastrophic failure resulting in the worst nuclear disaster in history. It was the result of a flawed reactor design that was operated with inadequately trained personnel.

The resulting steam explosion and fires released at least 5% of the radioactive reactor core into the atmosphere and downwind – some 5200 PBq (I-131 eq).

Two Chernobyl plant workers died on the night of the accident, and a further 30 people died within a few weeks as a result of acute radiation poisoning.

Resettlement of areas from which people were relocated is ongoing. In 2011 Chernobyl was officially declared a tourist attraction.

Radiation from Chernobyl was measured not only in Northern and in Southern Europe, but also in Canada, Japan and the United States. Only the Southern hemisphere remained free of contamination.

Experts conclude some cancer deaths may eventually be attributed to Chernobyl over the lifetime of the emergency workers, evacuees and residents living in the most contaminated areas. These health effects are far lower than initial speculations of tens of thousands of radiation-related deaths

Buncefield- December 2005









Refinery Explosion Mexico



Pipeline Incidents

ConocoPhillips Refinery Incident 2001

Figure 1 - Diagram of the SGP

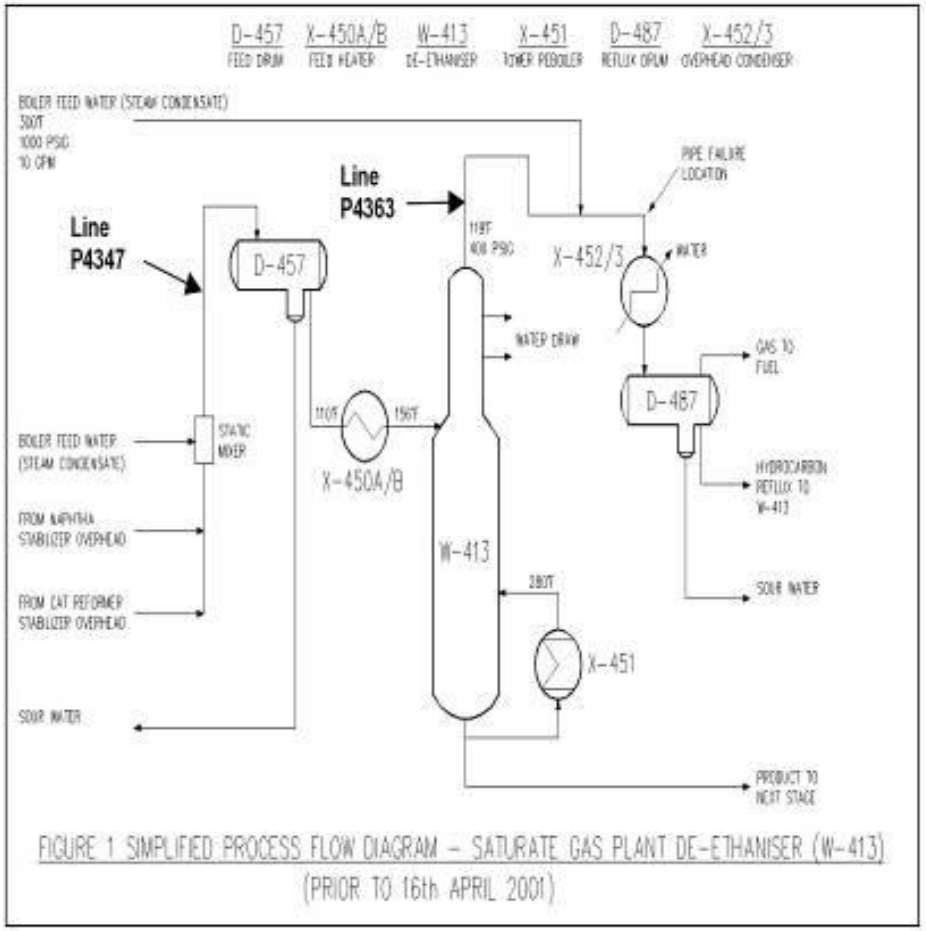
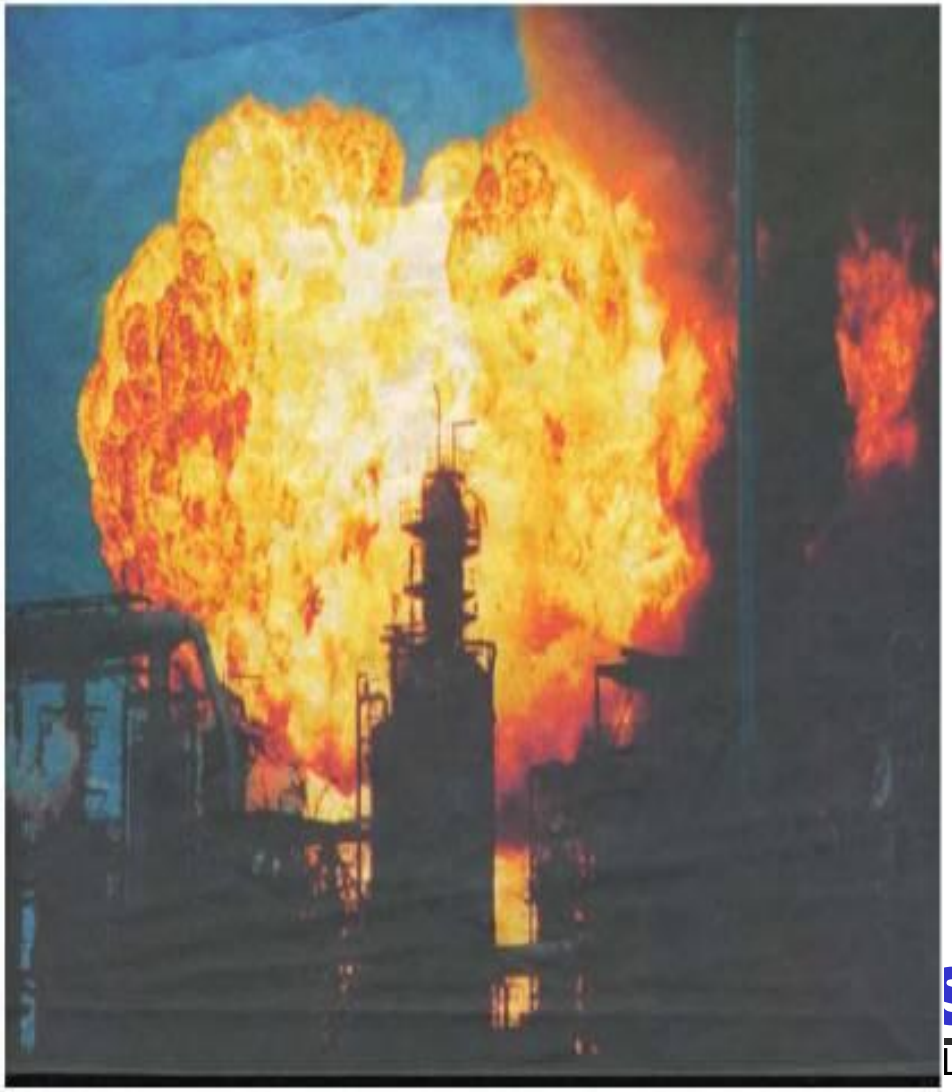


FIGURE 1 SIMPLIFIED PROCESS FLOW DIAGRAM – SATURATE GAS PLANT DE-ETHANISER (W-413)
(PRIOR TO 16th APRIL 2001)

Figure 2 –The fire and secondary fireball - photo courtesy of Andy Trott



Internal Corrosion Caused This Failure

Figure 3 – Damage to the SGP after the explosion (W413 column to the right)



Figure 5 – Close up views of damage to the SGP



Damage Caused by Internal Corrosion on Gas Line on Bend Near Chemical Injection Point

Figure 6 – Close up views of damage to the SGP



Figure 7 – The failed elbow recovered from the plant



ConocoPhillips Refinery Incident 2001

Figure 8 – Diagram of the pipework

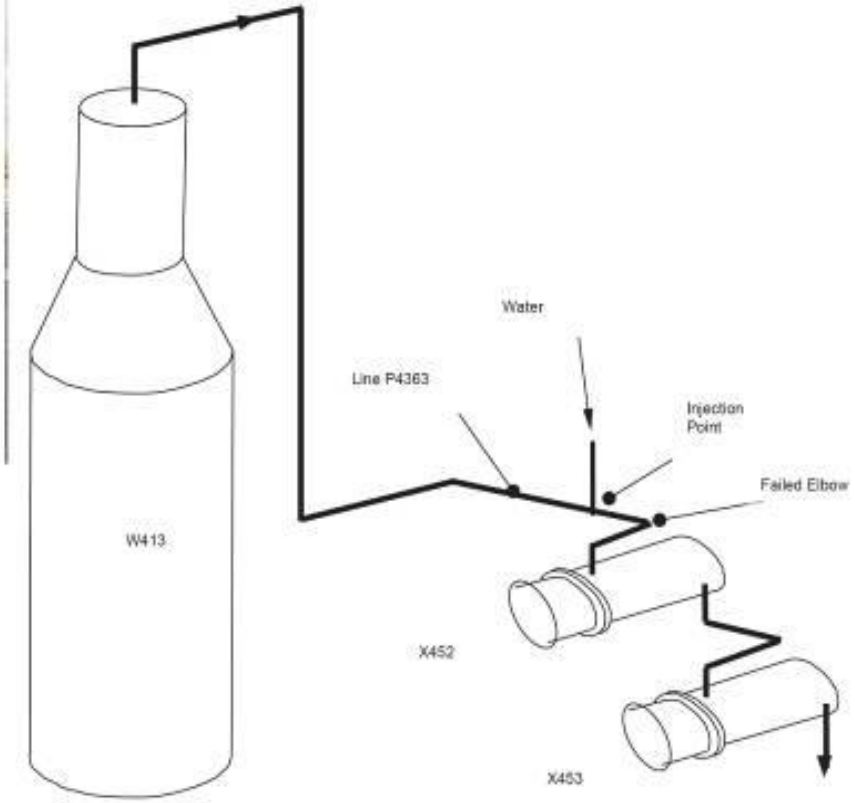
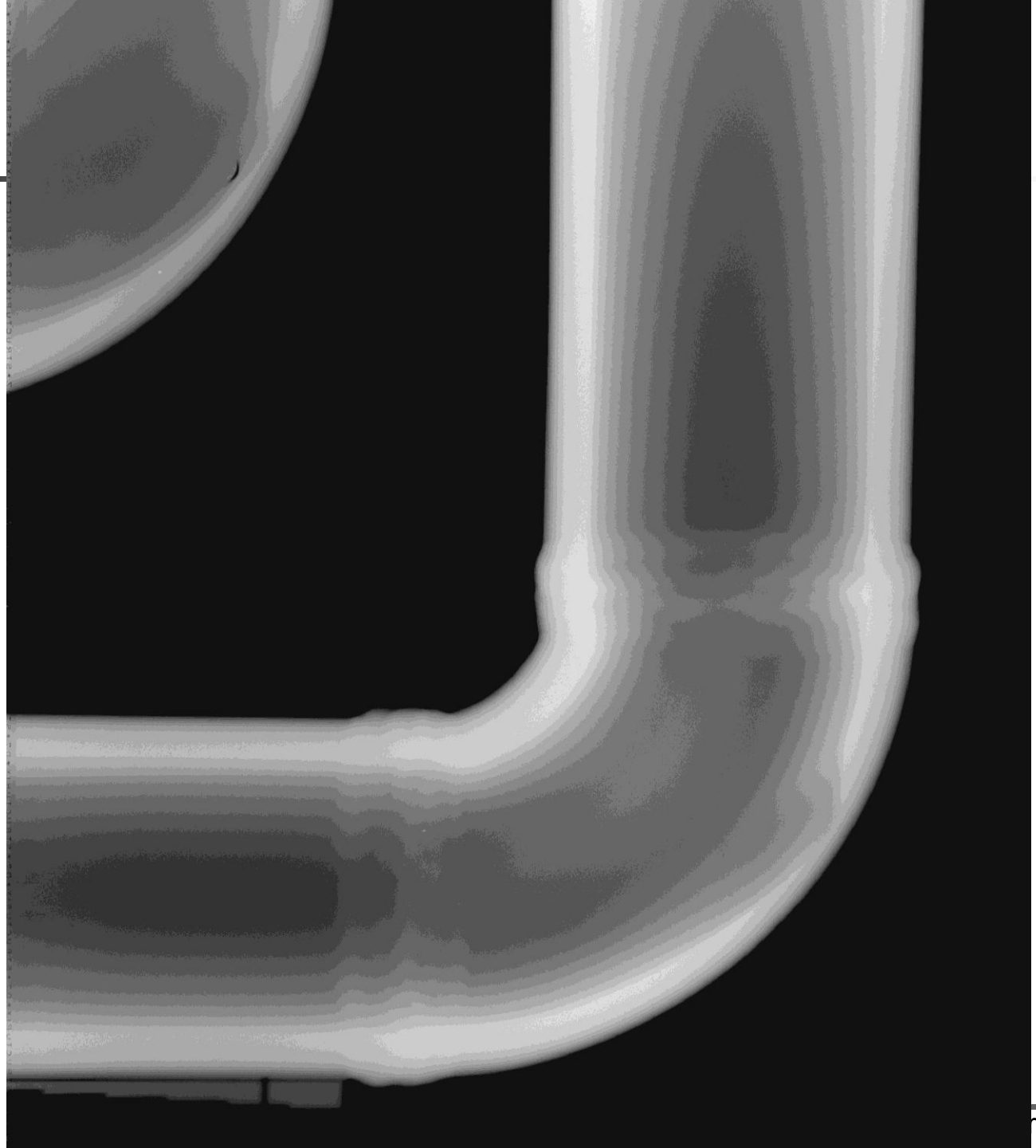


Figure 9 – In-situ failed elbow and injection pipework connection (broken off)







D-4008 - 4"-SCM-14153-1A1f-Ih
EROSION OF BEND DOWN - STREAM OF CONTROL VALVE LRC-4018.


0MM
50
100
150

Corrosion Failure Caused This



Varanus Island

- Cost for repair $ 30m
- No injuries
- Loss of production cost $ 200m western Australian lost 30% of its gas supply for 2months
- Cause corrosion and incorrect checking and operation of CP
- Explosion removed a lot of evidence



Photos of Incident



4 a)

Photo 8 -Damaged gas plant



4b)

Adjidabiya Reservoir



Indication of Pipe Size



Effect of Corrosion on the Great Man Made River Pipeline





Water Leakage Pipeline Design Life 50 Years Failed after 10 years worlds costliest corrosion failure £3Bn no CP applied if it was a lot of the damage could have been prevented





Water Leakage Pipeline Design Life 50 Years Failed after 10 years worlds costliest corrosion failure £3Bn no CP applied if it was a lot of the damage could have been prevented



Damaged Pipe Section





Carlsbad, New Mexico - Aug 2000





Gas Line,
12 dead,
86ft crater,
Internal corrosion
suspected.



What are the Possible Failure Modes ?

- General types of degradation mechanisms that can cause failure of pressure equipment, like:
  - General and localized corrosion and erosion
  - Environmentally assisted cracking e.g SCC
  - Metallurgical aging and degradation
  - High temperature degradation and brittle fracture
  - Mechanical cracking and damage
  - Welding and fabrication flaws
  - Corrosion under disbonded coatings
  - AC/DC stray current
  - Galvanic corrosion
  - Bacterial corrosion

- Anything that will cause materials of construction to degrade and possibly cause failure of pressure equipment in service



Shanghai LNG Terminal Why We Hydrotest Pipelines



Apparent failed 36” flange







BP Texas Refinery Incident

© IACS Corrosion Engineering Ltd

Details

- The **Texas City Refinery explosion** occurred on March 23, 2005, when a hydrocarbon vapor cloud was ignited and violently exploded at the isomerization process unit at BP's Texas City refinery in Texas City , Texas killing 15 workers, injuring 180 others and severely damaging the refinery. The Texas City Refinery was the second-largest refinery in the state, and the third-largest in the United States with an input capacity of 437,000 barrels (69,500 m^3) per day as of January 1, 2000. BP acquired the Texas county refinery in 1999.

Figure 2. Dimensionally identical piping elbows on RHU heat exchangers A and B.



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

Lower left arrow --
Carbon steel elbow 1

CSB Investigation Reports are formal, detailed reports on significant chemical accidents and include key findings, root causes, and safety recommendations. CSB Hazard Investigations are broader studies of significant chemical hazards. CSB Safety Bulletins are short, general-interest publications that provide new or noteworthy information on preventing chemical accidents. CSB Case Studies are short reports on specific accidents and include a discussion of relevant good practices for prevention. All reports include safety recommendations when appropriate. CSB Investigation Digests are plain-language summaries of investigation Reports.

Incident Description

On July 28, 2005, at about 6:00 pm, an RHU hydrogen gas heat exchanger process pipe ruptured. The venting hydrogen gas ignited and a huge fireball erupted in the unit. One employee sustained a minor injury while assisting with the RHU emergency shutdown. The RHU sustained major damage from the hydrogen-fed fire that burned for two hours. There were no offsite impacts but, as a precaution Texas City ordered a shelter-in-place for nearby residents until the fire was contained.

BP personnel examined the extensively damaged unit and determined that an 8-inch diameter pipe elbow on an RHU heat exchanger hydrogen gas outlet pipe ruptured (Figure 3). The BP investigation team recovered the elbow segments that remained attached to the pipe and three pieces found in the debris (Figure 4).

- *The venting hydrogen gas ignited and a huge fireball erupted in the unit.*

Figure 3. Ruptured 8-inch pipe elbow on heat exchanger A outlet.



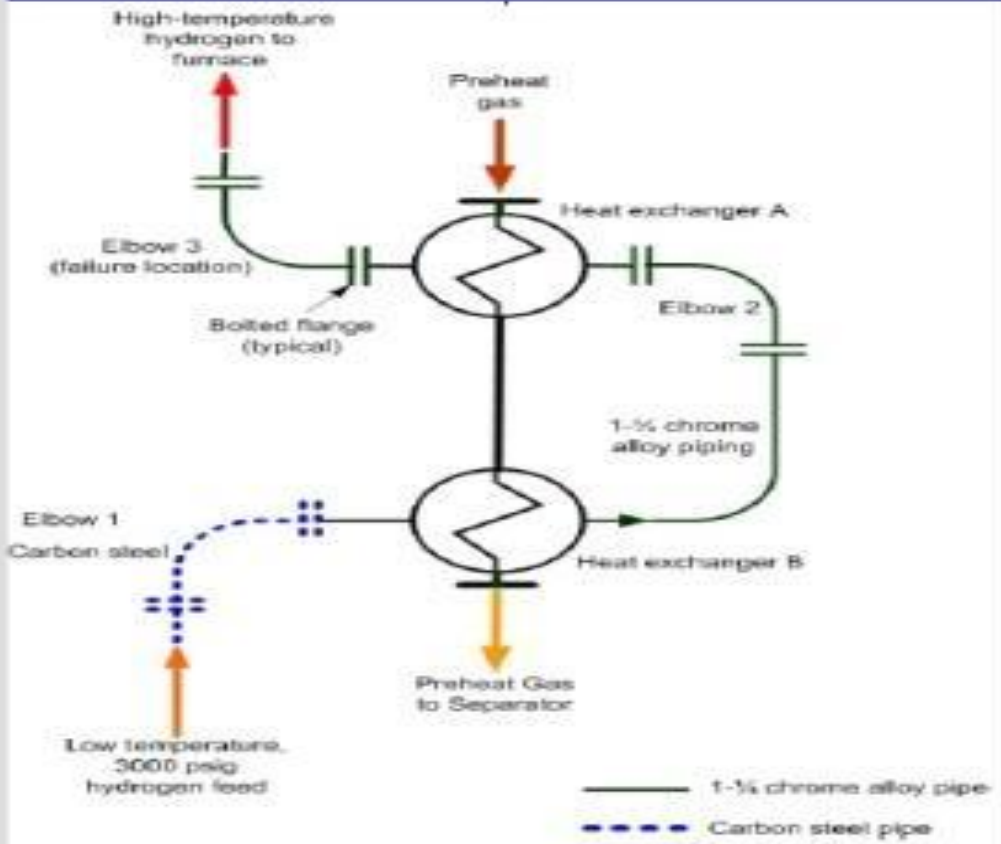
Figure 4. Ruptured 8-inch carbon steel pipe elbow pieces recovered after the fire



Upper left -- Carbon steel elbow segments (view of inside surface)
Above -- Flange segments
Lower left -- Close-up of fissure on middle elbow segment

- *BP personnel examined the extensively damaged unit and determined that an 8-inch diameter pipe elbow on an RHU heat exchanger hydrogen gas outlet pipe ruptured . . .*
- *The BP investigation team recovered the elbow segments that remained attached to the pipe and three pieces found in the debris . . .*

Figure 5. RHU hydrogen heat exchanger piping material requirements.



dimensions been different, elbow 1 would not have been interchangeable with elbow 2 or 3 (see Figure 2).

Because of this component interchangeability, any heat exchanger piping disassembly/reassembly for maintenance or repair requires the maintenance crew to be careful to install each elbow in the correct location. Because carbon steel and low alloy steel are visually indistinguishable, special test equipment* is needed to distinguish the two low alloy steel elbows from the carbon steel elbow. Otherwise, to prevent switching elbow 2 or 3 with incompatible carbon steel elbow 1, the crew must clearly label or mark each elbow before removing them, then confirm that each has been reinstalled in the correct location.

The results, compared to existing experimental data and empirical service life predictions, concluded that the elbow failed after being in service for fewer than 3000 hours.

* Portable hand-held test devices, such as an x-ray fluorescence instrument, quickly distinguish between carbon steel and alloy steel piping materials without damaging the test article.

Pipeline Failure Data

Ageing Asset

- The UK pipeline system is an ageing asset and as pipelines gets older corrosion becomes an increasing possibility and more a likely failure mode.
- Control of pipeline corrosion is essential but in order to do so we need to understand the corrosion mechanism, possible failure modes and be aware of situations that can lead to failure.
- Cathodic protection is a method of corrosion control, but CP systems do need to operated and maintained in accordance with recognised standards

Risks to Pipelines

- Third Party Damage is one of the main risks to pipeline systems and vantage point surveys help mitigate and control the risk
- Corrosion is now a major risk to the pipeline system mainly external corrosion and is controlled by CP and use of high quality coatings. AC corrosion can be a significant risk
- Operator error or incorrect maintenance
- Unintentional hot taps
- Material defects general during construction
- Ground movement

Sources of Reference

- European Gas Industries Group (EGIG) maintain data base
- EGIG is a cooperation of seventeen gas transmission system operators in Europe, and it is the owner of an extensive database of pipeline incident data collected since 1970.
- Latest report is the 12th issued Dec 2024
- 19 gas operators throughout Europe contribute

Latest EGIG Data

- The number of corrosion incidents is decreasing and corrosion is now comparable to third party damage as a main failure mechanism for pipelines. Small diameter and wall thickness pipes were most likely to suffer from corrosion.

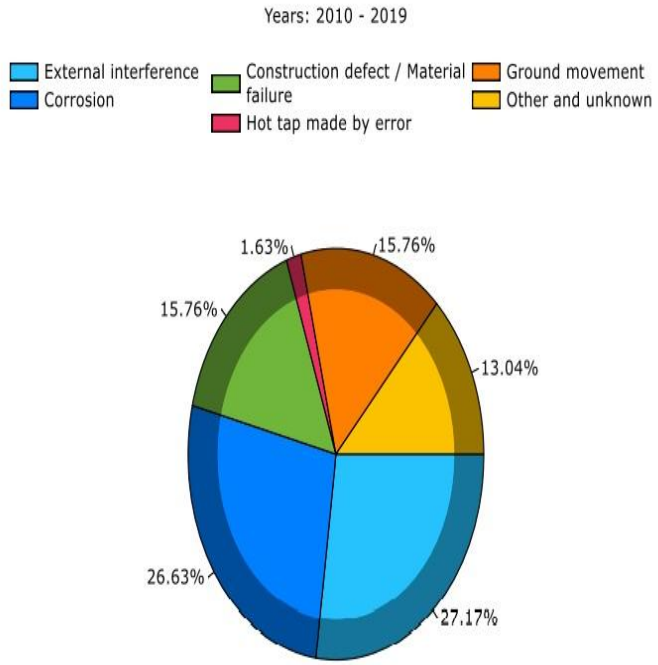


Figure 14: Distribution of incidents (2010–2019)

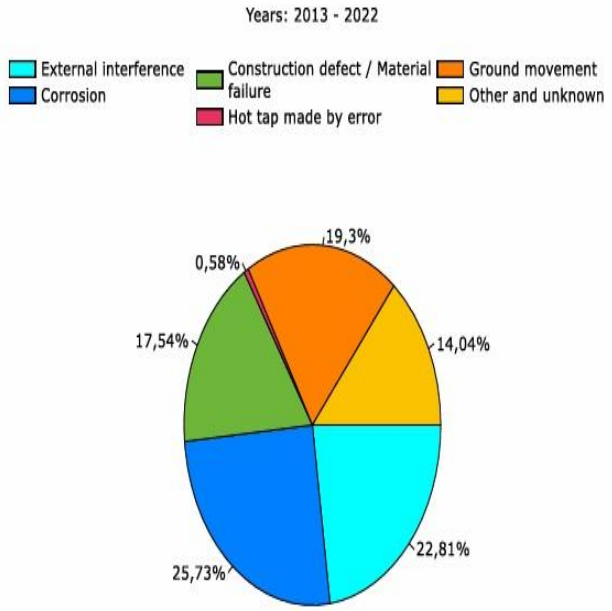


Figure 13: Distribution of incidents (2013–2022)

Third Party Damage Risk Decreasing

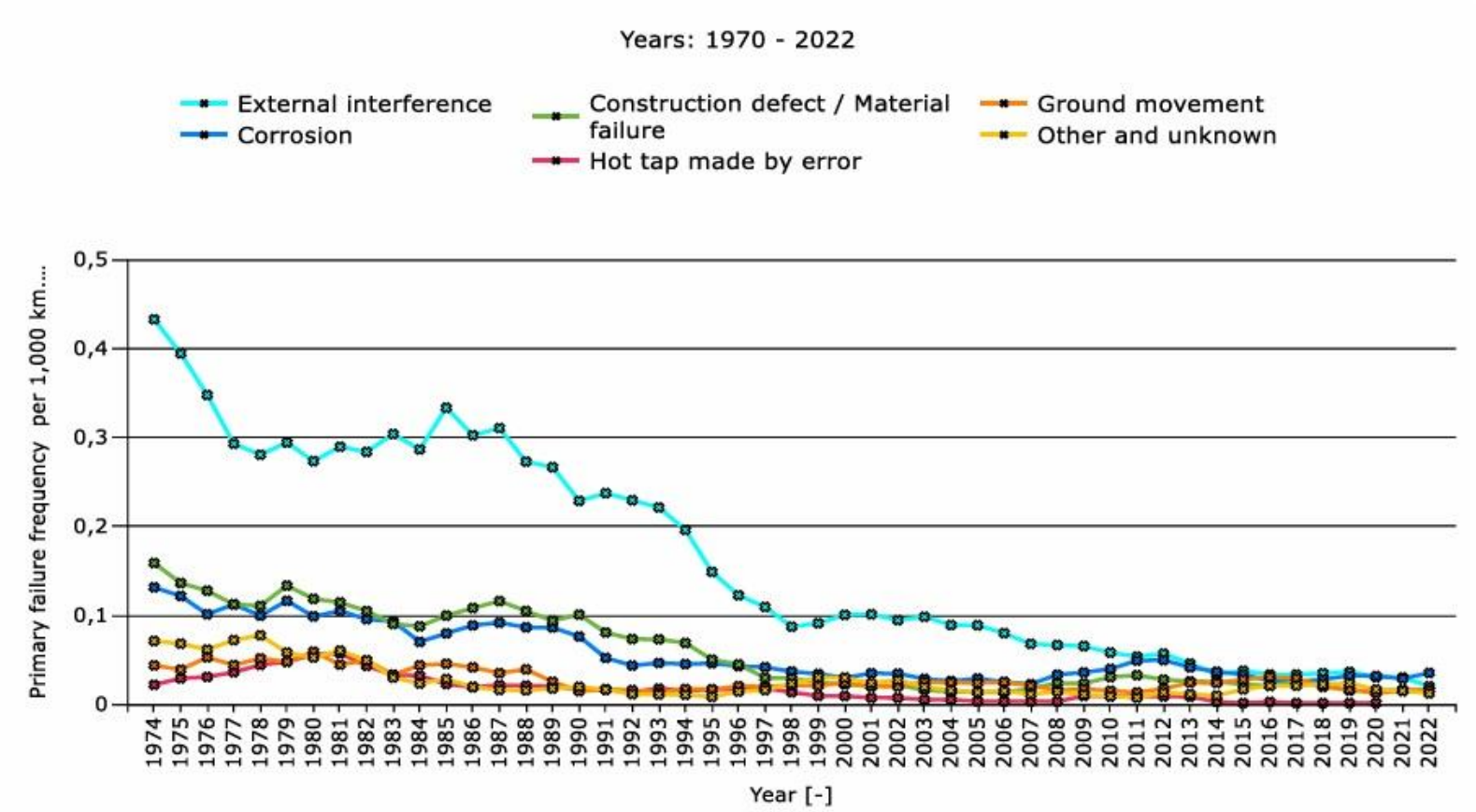


Figure 14: Primary failure frequencies per cause (five year moving average)

Cause and Nature of Damage to Gas Pipelines

- If a large leak is to occur the most likely cause used to be external interference or ground movement.
- Similar statistics apply to pipeline rupture
- Corrosion should not result in large leak of product.
- Corrosion has now overtaken 3rd party damage as a failure mechanism and the HSE are aware of this

Hole Size and Cause

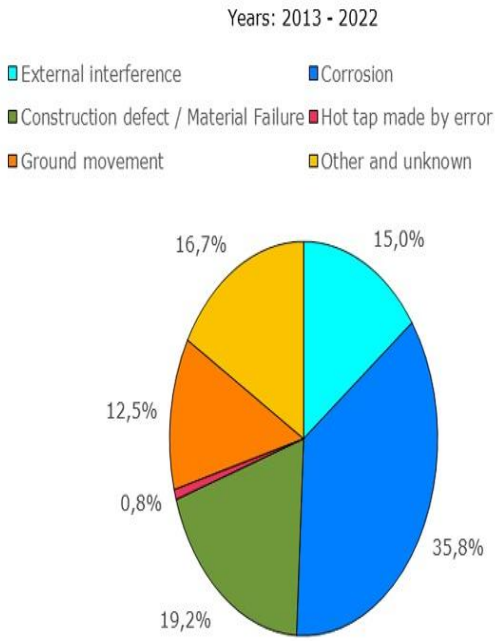


Figure 17: Distribution for incidents with leak size: pinhole/crack (2013-2022)

Failure Causes

Cause	Primary failure frequency per cause			
	1970-2022 per 1,000 km·yr	2003-2022 per 1,000 km·yr	2013-2022 per 1,000 km·yr	2018-2022 per 1,000 km·yr
External interference	0.125	0.044	0.027	0.020
Corrosion	0.049	0.033	0.030	0.035
Construction defect / Material failure	0.046	0.022	0.021	0.016
Hot tap made by error	0.012	0.003	0.001	0.000
Ground movement	0.025	0.021	0.023	0.016
Other and unknown	0.021	0.015	0.017	0.012

Table 2: Primary failure frequencies per cause

From the EGIG data it can be seen that corrosion represents about 27.3% of all reported failures of high pressure gas pipelines. External interference or third party damage is not now the highest cause of failure at 22.8%. The failure rate due to corrosion is high and now exceeds to that for third party interference. The Table also represents all historical data as a percentage of recent failures. This shows corrosion is an increasing as a failure mechanism as well

Failure Frequency and Type

Leak size	Failure frequency per 1,000 km·year					
	External interference	Corrosion	Construction defect / Mat. Failure	Hot tap made by error	Ground movement	Other and unknown
Unknown	0.0000	0.0000	0.0014	0.0000	0.0000	0.0014
Pinhole/crack	0.0124	0.0296	0.0158	0.0007	0.0103	0.0138
Hole	0.0117	0.0000	0.0014	0.0000	0.0055	0.0007
Rupture	0.0028	0.0007	0.0021	0.0000	0.0069	0.0007

Table 4: Primary failure frequency, cause and size of leak (2013-2022)

Failure and Year of Construction

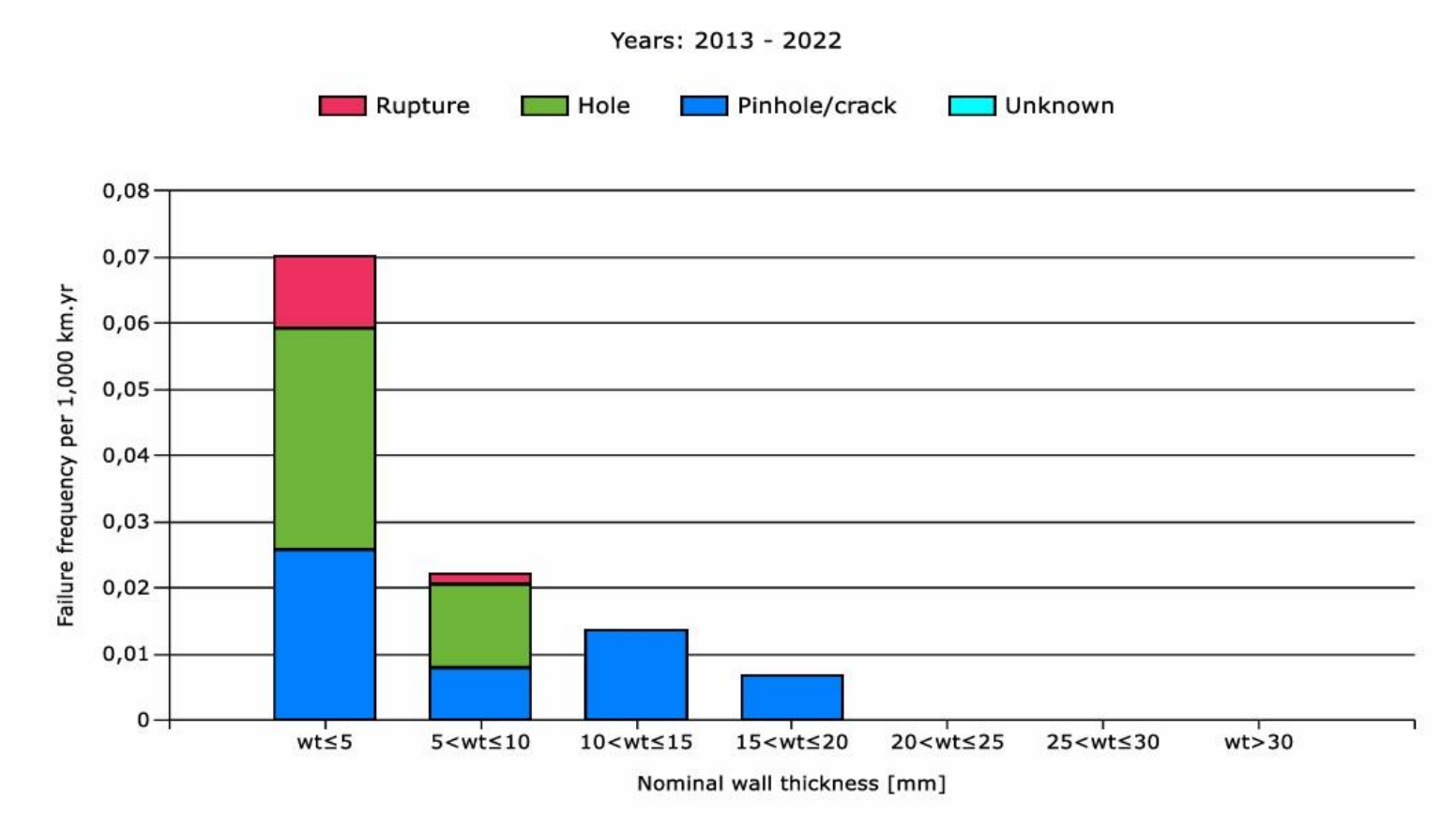


Figure 31 : Relationship external interference, size of leak and wall thickness (wt) (2013-2022)

Coating Type and Corrosion Failure

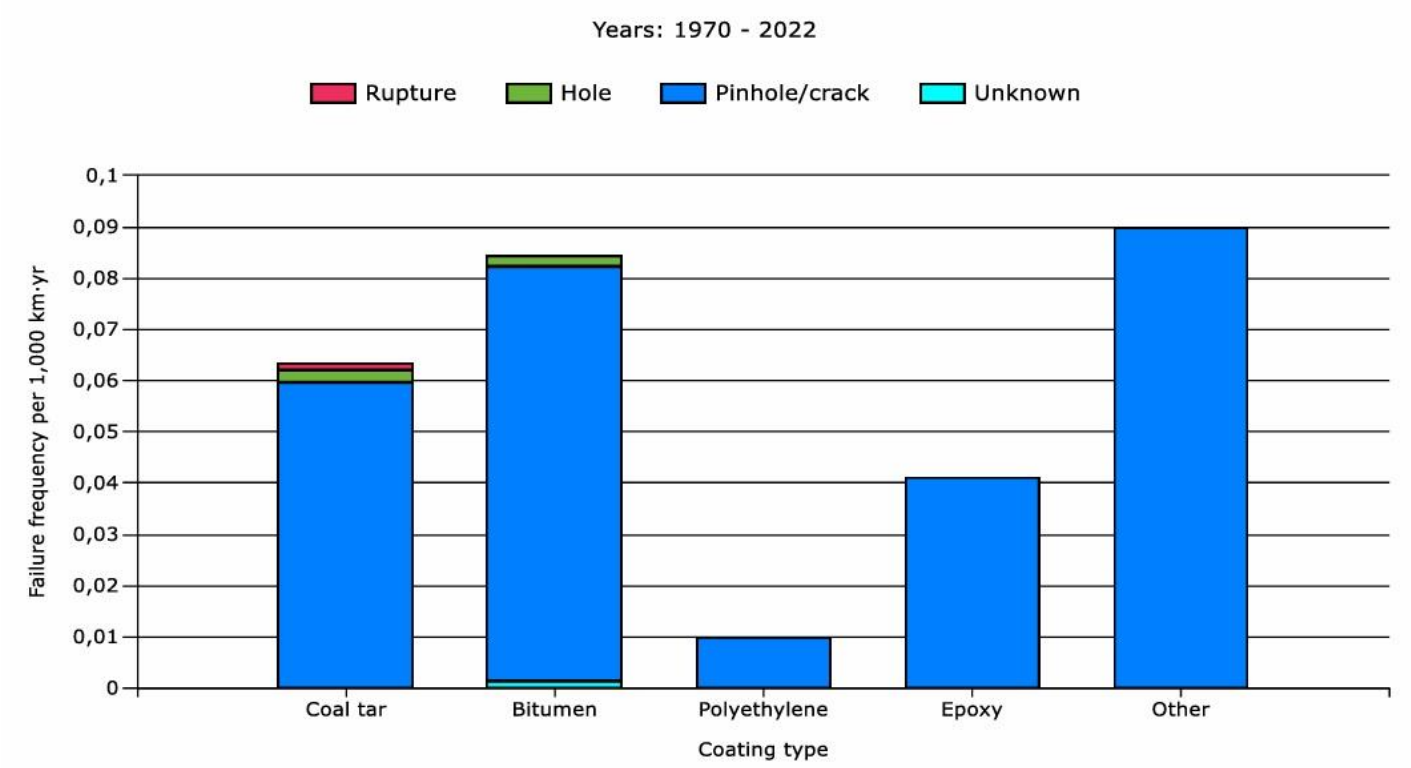


Figure 34: Relationship corrosion, leak size and coating type (1970-2022)



Pipe Diameter and Corrosion

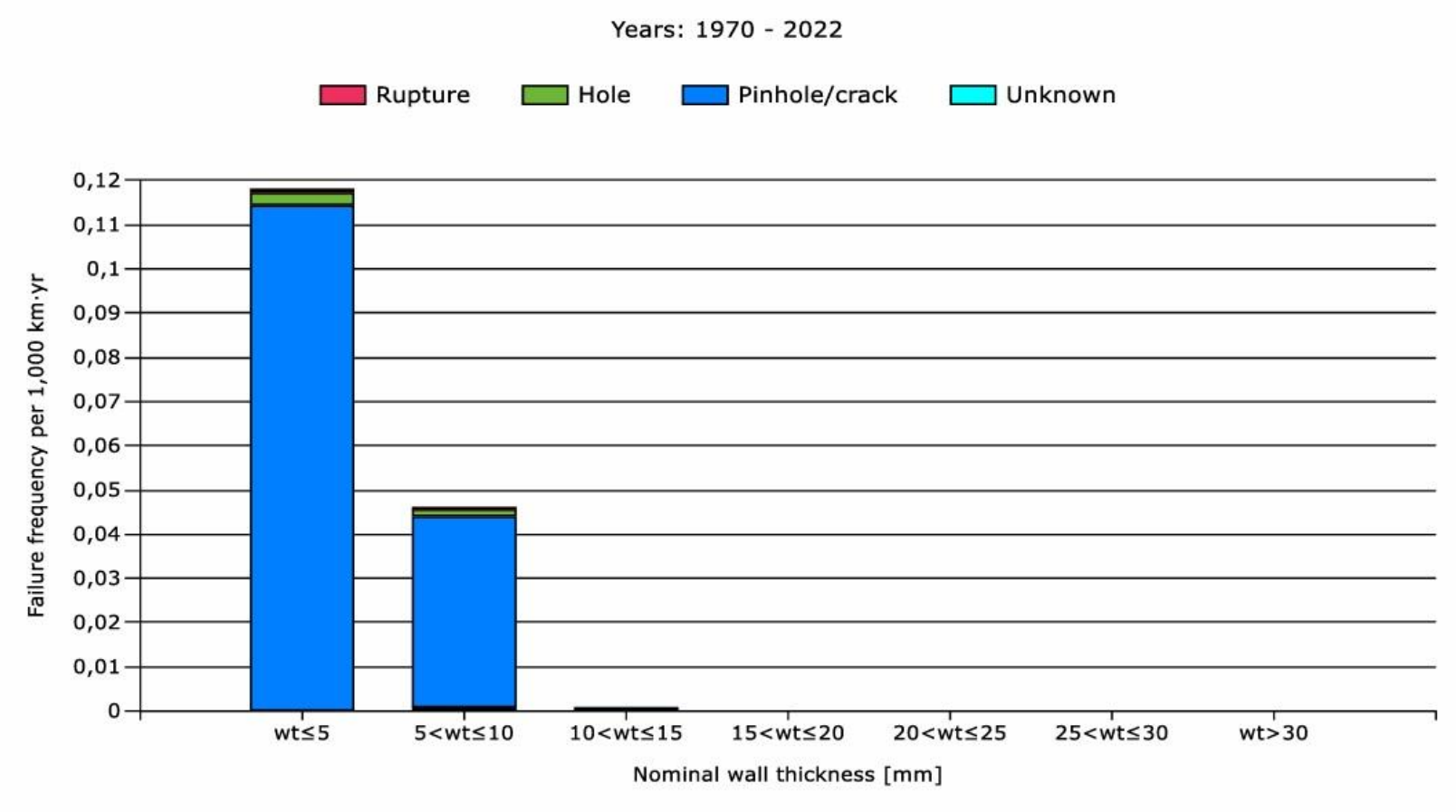


Figure 36: Relationship corrosion, size of leak and wall thickness (wt) (1970-2022)

So what does EGIG data tell us ?

- Corrosion rather than external interference is now the main cause of failure (not surprising as we have an ageing asset)
- The greatest risk is on smaller diameter and smaller wall thickness pipe and lower diameter.
- These factors help us when prioritising risk
- That is look at lower diameter pipelines and those with reduced wall thickness first

Beware

- Pipelines will suffer corrosion at a typical uniform rate but localised pitting can occur
- So older pipelines, thinner wall smaller diameter lines are more likely to fail first.
- Need to risk rank pipelines and in that way, you can prioritise those that need working on.
- Look at where located, previous histories and if a risk of aggravated corrosion e.g. low resistivity soils or stray current.
- Need to remember that at some locations we can get an accelerated corrosion risk

Where do we get higher corrosion rates ?

- DC stray current
- AC interference
- Bacterial corrosion
- Galvanic corrosion e.g contact with dissimilar metals earthing, reinforced concrete.
- High temperature environments
- Corrosion under insulation
- Reverse polarity

Going Forward

- The HSE know that corrosion is a major risk to pipelines.
- SGN needs to demonstrate that it takes this risk seriously
- SGN should have a robust management plan to manage this risk
- The fact that SGN has a number of HSE enforcement plans is a concern.

UKOPA Data MAHPs UK

3.2 Transported Products

The reported lengths (in km) of pipeline in operation at the end of 2023, by transported product, are shown in Table 3.1.

Product	Length (km)	%age of Total
Natural Gas (Dry)	21,408.22	92.4
Ethylene	1,140.94	4.9
Natural Gas Liquids	251.00	1.1
Crude Oil (Spiked)	212.60	0.9
Ethane	38.10	0.2
Propylene	37.00	0.2
Condensate	24.00	0.1
Propane	19.50	0.1
Butane	19.50	0.1
Hydrogen	14.14	0.1
TOTAL	**23,165**	**100.0**

Table 3.1: 2023 Pipeline Operating Lengths

Work Near a 2 bar gas line



Don’t upset Farmers

- It is not just electrical hazards you need to be aware of when working on pipelines
- Don’t upset landowners as it can backfire and they can show their displeasure



SGN Romsey Failure



San Bruno Gas Pipeline Explosion US

California gas line explosion the death toll was 13 people. The massive pipeline explosion and fire that consumed 37 homes in San Bruno, just south of San Francisco . The 30" diameter high-pressure natural-gas pipeline was installed in 1956,ruptured shortly after 6pm local time on Thursday, September 9 2008.

The explosion was so strong that USGS seismometer recorded it as a 1.1 magnitude earthquake.

The failure cause was not known but it could have been due to seismic activity



Ethylene fire US



Stockline Glasgow

- The blast at the ICL Plastics factory has been described as Scotland's worst industrial disaster since Piper Alpha. It was caused by a leak from a corroded underground LPG (liquefied petroleum gas) pipe passing through a wall into the basement of the factory. The gas was probably ignited by an electrical spark when someone activated the lights.
- Nine people killed
- No CP applied to the onsite pipework



Action

- SGN will in the future need to ensure that the CP systems on its buried pipelines are effective
- If any issues are identified, make sure that these are prioritised- Don’t just leave them!
- Put any observations in writing
- Pipelines are getting older and CP is the main means of preventing corrosion so there needs to be greater emphasis on control of pipeline corrosion

Corrosion Features

- Often we undertake excavations to look at Inline Inspection (ILI) features.
- These just identify the fact that there is corrosion but never the cause.
- This is a gas industry wide issue that needs to be addressed
- When undertaking P11 inspections should not just identify it is corrosion but also indicate the cause.

Summary

- We have a lot to go through and may not cover it all in 2 days
- Lots of things to cover
- Remember that not all standards are correct especially the GIS ones they don't seem to be really checked before issue.
- Even if one thing I have identified is picked up in this course it can save an incident so it would be worth it.
- I will highlight that SGN do not do things in accordance with standards, but you are not alone other operators don't either.