Developments in Leak Detection Systems and Regulatory requirements

Onshore cross-country oil pipelines (crude oil & products)

Wim Guijt
Principal Technical Expert Onshore Pipelines

Agenda

Introduction
Bow-Tie: Threats, Loss of Containment (LoC) and Consequences
Leak Causes: Comparison Europe - Concawe and USA - DoT PHMSA
Concawe Spill size distribution and relation between Spill size & cost (US DoT PHMSA)
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Introduction

- Shell Goal Zero ambition: No Harm & No Leaks (Annual Sustainability Report)

- Consequences of a pipeline leak could be very significant
  - People, Asset, Community & Environment (Shell Risk Assessment Matrix - RAM)

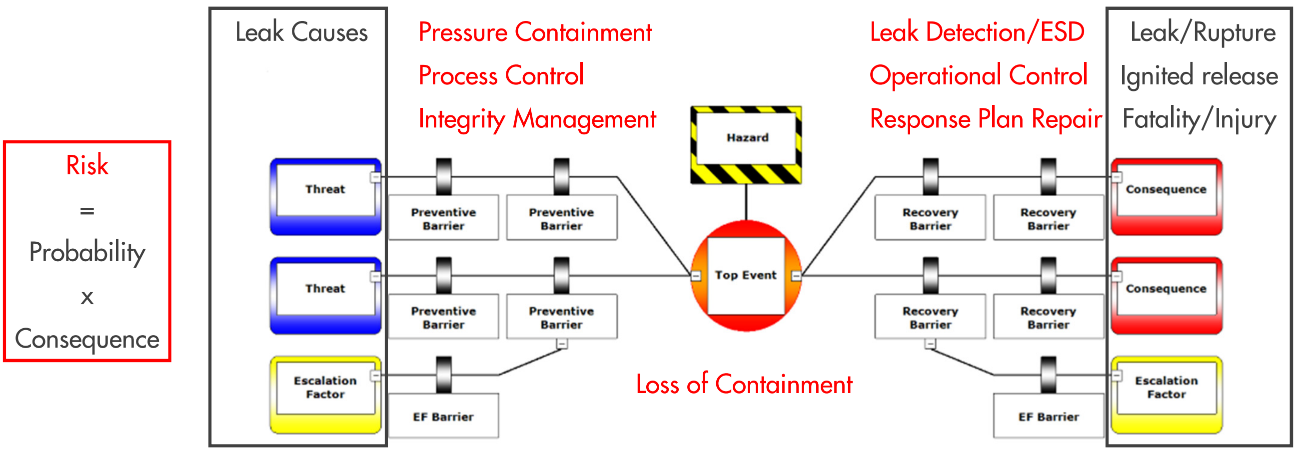
Gas pipeline incidents with multiple fatalities	PG&E San Bruno, Fluxys Belgium
Oil pipeline incidents, multiple fatalities	Equilon, Shell/Texaco JV, Olympic pipeline
Leaks get wide media coverage, having significant impact	TransCanada, Keystone (XL)
Environmental damage, clean-up & repair cost	Enbridge, Marshall: ~$1 billion!

  - Costs/impact of deferred or even missed production could also be very significant

A (minor) leak could require shut-in of pipeline systems	Ineos, Forties Pipeline System shut-in
Have emergency and repair procedures/equipment in place	e.g. critical export lines

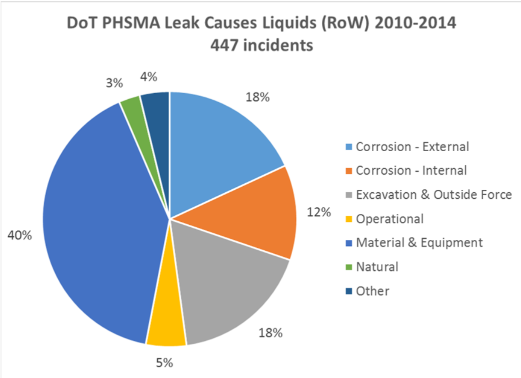
Bow-Tie: Threats, Loss of Containment (LoC) and Consequences

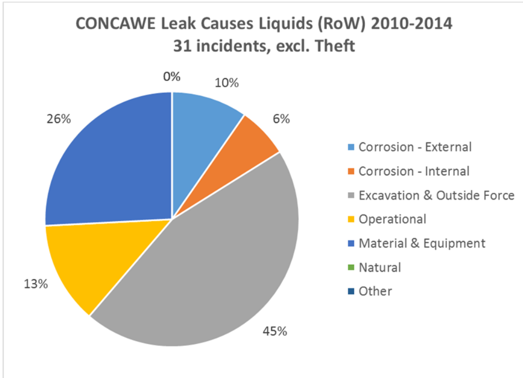
- Focus primarily on prevention, i.e. reduce failure frequency (**Likelihood or Probability**)
- Leak Detection (& ESD valves): reduce **Consequences/Severity** (People, Asset, Community & Environment)



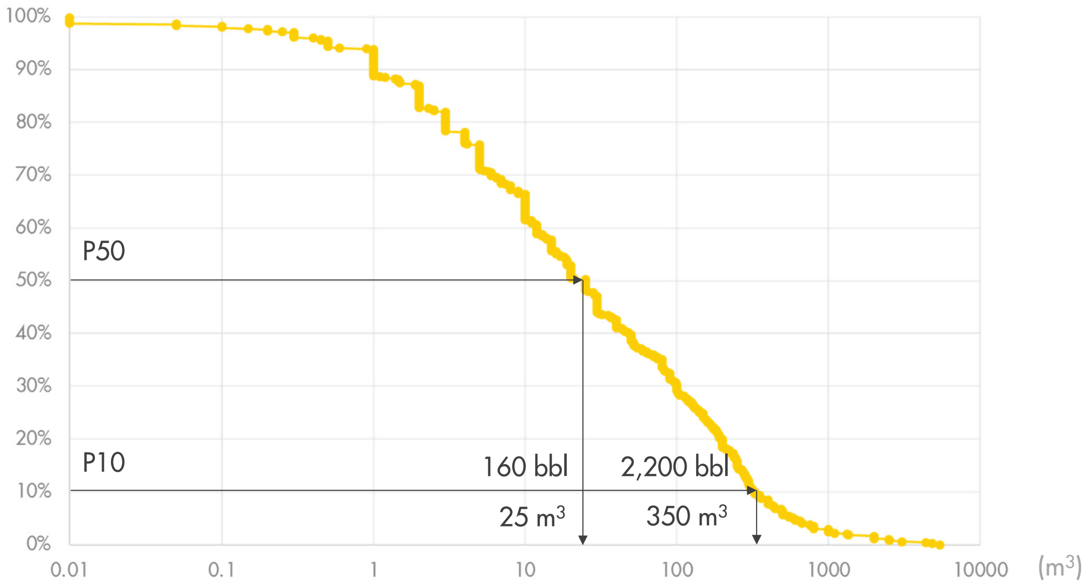
Leak Causes: Comparison Europe - Concawe and USA - DoT PHMSA Incident Statistics 2010-2014 (5 year period)

- Recent Incident frequencies for oil/product pipelines (RoW) comparable in US and EU
  - US: ~300,000 km Hazardous Liquids 0.3 incidents/1000km/year (~ 90/year)
  - Europe: ~35,000 km Oil/Products 0.2 incidents/1000km/year (~ 7/year)

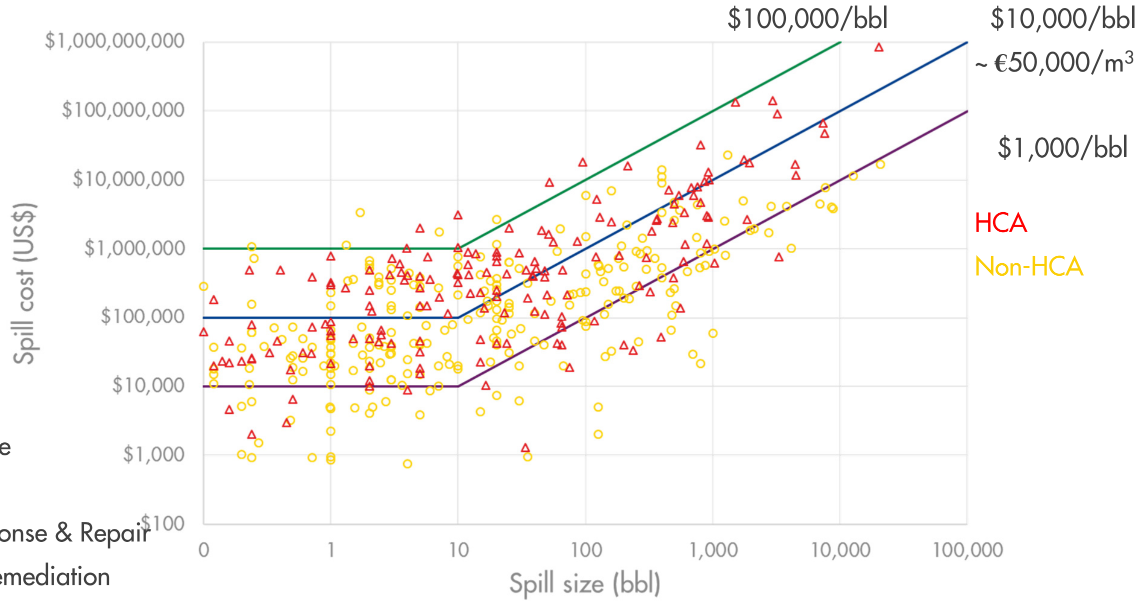




Concawe Spill size distribution (m^3)
No theft – 494 incidents reported with spill size



Relation between Spill size & Cost (US DoT PHMSA) 2010-2016



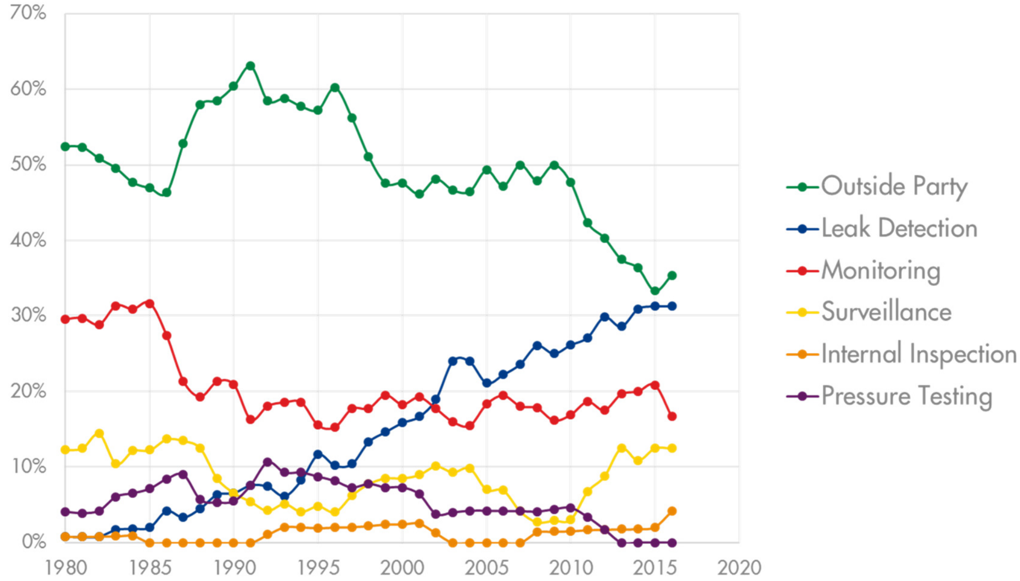
Costs include:

- Property Damage
- Commodity lost
- Emergency Response & Repair
- Environmental remediation

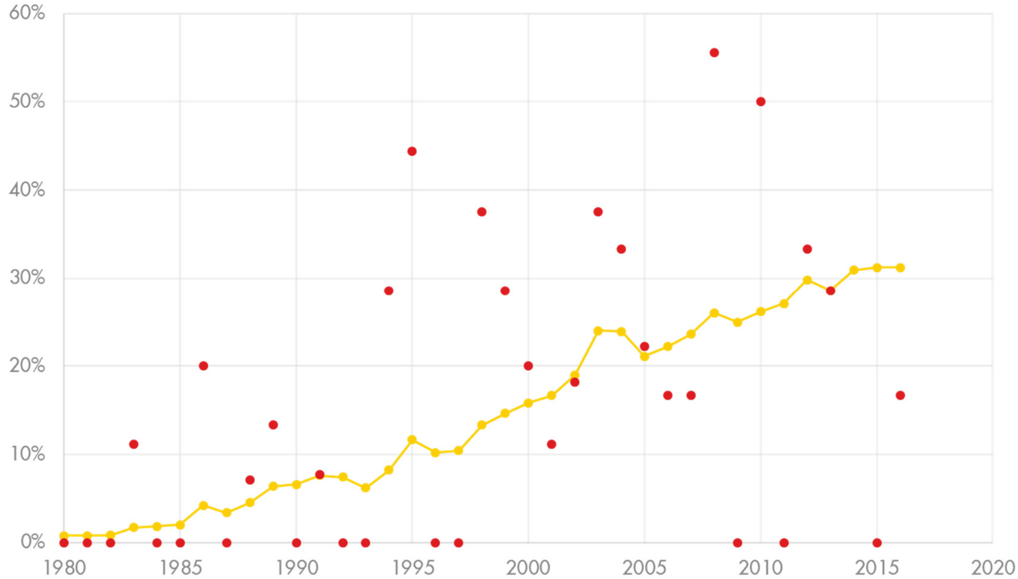
Leak Identifiers Concawe (no Theft) vs DoT PHMSA (RoW)

Identifier	CONCAWE 1971-2016		DoT PHMSA 2010-2016	
RoW Patrols (Surveillance)	36	9%	169	47%
Controller Monitoring	85	22%	13	4%
Leak Detection System	45	12%	36	10%
Pressure Testing	19	5%	6	2%
Outside Party	199	51%	139	38%
Internal Inspection	5	1%		
Total	389	100%	363	100%

Concawe Leak Identifiers (no theft, buried only) 10-year moving average (1980-2016)



Concawe: Leak Detection as Identifier (no theft, buried) Annual and 10-year moving average



Leak Detection Technologies & Performance
(based on Shell experience to date)

- Missed Leaks due to frequent False Alarms (trade-off between Confidence vs Sensitivity)
- LDS are engineered **Systems**, often limited in-house expertise & lacking KPI's
- No single LDS meets all requirements: Consider combining complementary systems, where required (HCA)

Leak Detection Method		API 1130						Additional Remarks Aim for no more than 1-2 false alarms/year per segment, ensuring confidence in LDS (Alarm Management)	
		Reliability (False Alarms, Complexity)	**Sensitivity** (Continuous %Q vs Time or Intermittent)	**Accuracy** (Location)	**Robustness** (Transients, Slack Flow, Batching)	**Cost** (CAPEX/OPEX)	C= Continuous I= Intermittent		
p&Q /RoC	p, Q Monitoring, Rate of Change						C	10% of Q in less than 3-5 minutes	Onset only
MVB/CMB	Volume/Mass balance						C	1%-5% of Q within an hour up to a day	Common for oil/product transport
SPLD	Statistical Pipeline Leak Detection						C	1%-5% of Q in minutes up to an hour	Mainly used for HVL
RTTM	Real Time Transient Model						C	Complex, Alarms, Cost	Extensive Model tuning
PW	(Negative) Pressure Wave						C	Sensitive (<1% of Q) and Fast (< 1 minute)	Onset only, on trial basis
VI	Visual Inspection						I	Inspection frequency	Varies per Region (US regulations)
PT	Pressure Test						I	Low Frequency & Offline only	Varies per Region (US regulations)
AP	Acoustic Pigging						I	Inspection frequency	Mainly used in Germany (TRFL)
FOC	Fiber Optic Cable						C	Very sensitive, frequent Alarms/Alerts	Trials only
VST	Vapour Sensing Tube						I	Sampling frequency, limited length	Incidentally for HCA's

Changing Regulatory influence in US

- Importance of Leak Detection duly recognised
  - Provisions included in 49 CFR 195
  - PIPES Act 2006, PHMSA released a Leak Detection Study (2007)
  - Advisory Bulletin ADB-10-01 issued in 2010 by PHMSA
  - A Leak Detection Report was released by PHMSA to Congress in 2012 under the Pipeline Safety, Regulatory Certainty, and Job creation Act of 2011
  - Various Tests and Studies (being) performed (PRCI, ELDER JIP)
- Following 2010 incidents even more focus on LDS
  - Enbridge - Marshall, undetected for 17 hrs
  - PG&E - San Bruno, 8 fatalities
- More focus also Offshore US (BSEE) and in Canada
  - Failure mode awareness, Alarm handling
  - Operator Training, Leak recognition, Procedures
  - Periodic Evaluation of LDS Performance

Regulations, Most referenced Codes & Standards for Leak Detection

- US, 49 CFR Part195 Transportation of Hazardous Liquids by Pipeline
    - §195.444 CPM leak detection.
    - Each computational pipeline monitoring (CPM) leak detection system installed on a hazardous liquid pipeline transporting liquid in single phase (without gas in the liquid) must comply with API RP 1130 (incorporated by reference, see §195.3) in operating, maintaining, testing, record keeping, and dispatcher training of the system.
    - No explicit requirement for a CPM, but generally used for Liquid pipelines
    - No specific requirements for leak size, detection time, leak location, false alarm rate, Technology
  - API RP 1130 (2012) Computational Pipeline Monitoring for Liquids (API Publication 1155 in Annex C)
  - API RP 1175 (2015) Pipeline Leak Detection - Program Management
  - API TR 1149 (2015) Pipeline Variable Uncertainties and Their Effects on Leak Detectability
- Germany: TRFL defines specific requirements for LDS (see separate slide)
- Canada: CSA Z662 Annex E Recommended Practice for liquid hydrocarbon pipeline system leak detection
- DNVGL-RP-F302 (2016) Offshore Leak Detection

The Way Forward based on API RP 1175
Define KPI's for LD System and Drive Continuous Improvement

- Leak Detection System: Technology, Procedures, People
- Leak Detection Program Management is now covered in API 1175 (KPI's)
- Define Procedures, Roles & Responsibilities
- Plan-Do-Check-Act for continuous improvement:
  - Define Leak Detection Strategy and Select LDS method
  - Maintain MoC to track modifications to system design
    - Procedures, Roles& Responsibilities, Training, Maintenance LDS
  - Monitor Performance (Alarm Management) of LDS using KPI's
  - Improve LDS planning and adjust Strategy, if required

Questions and Answers

Q&A

Summary

- Leak Detection Technologies are important to reduce Consequences of leaks (size)
- Clean-up costs of leaks can be very significant, based on US statistics
- No single Leak Detection Technology/Method can meet various requirements
- Combining complementary and independent Methods improves Leak Detection Performance and reliability
- Aim to minimize number of false alarms, setting realistic detection thresholds
- Define KPI's upfront and track System performance, aiming for Continuous Improvement

German TRFL requirements for LDS

TRFL lists following functional requirements:

- 2 continuous independent Systems (based on different physics) for Steady State
  - 1 of these continuous Systems also functional under Transients, or another
- A System operational during Shut-in
- A System to detect minor gradual Seepages
- A System for Leak Location

- Methods listed under TRFL
  - Line Balance, Volume Balance, Flow monitoring, Compensated Mass Balance, Pressure monitoring, Pressure Wave, RTTM, Analytical / Vapour Sensing Tube (VST)