CASLC, Prevention First, September 26, 2018 – Long Beach, CA

Leading Safety, Health, and Environmental Indicators in Oil and Gas Industry (with the Focus on Hydraulic Fracturing)

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Introduction

- **Incidents:** financial and environmental damages, harm the reputation and sully the image of the industry

- Nov. 4 (2014) Referendum in *Denton, TX* : banned fracturing

Brandi Korte / Frack Free Denton

Need to alleviate public's *concern* and get their CONFIDENCE

Introduction

- Proactive system-oriented approach: helps in sustainable shale industry

- Efforts put on prevention translates into:

  - Safer industry - Social acceptance - Higher production

Need to Learn From Other Industries!

Leading Indicators: key in assuring safer operations

Leading and Lagging Indicators

- **Lagging Indicators:** facts about previous events, after an incident occurs (e.g. injury rates)

- **Leading Indicators:** pre-incident measurements, have a predictive quality (e.g. monitoring gas level)

- Application of indicators in upstream and downstream industries:
  - **NAE/NRC (2011)**: the BP Deepwater Horizon accident
  - **CBS (2007)**: BP Texas City Refinery incident
  - **CBS (2014)**: Tesoro Anacortes Refinery incident
  - **CBS (2015)**: Chevron Richmond Refinery

- Types and Characteristics

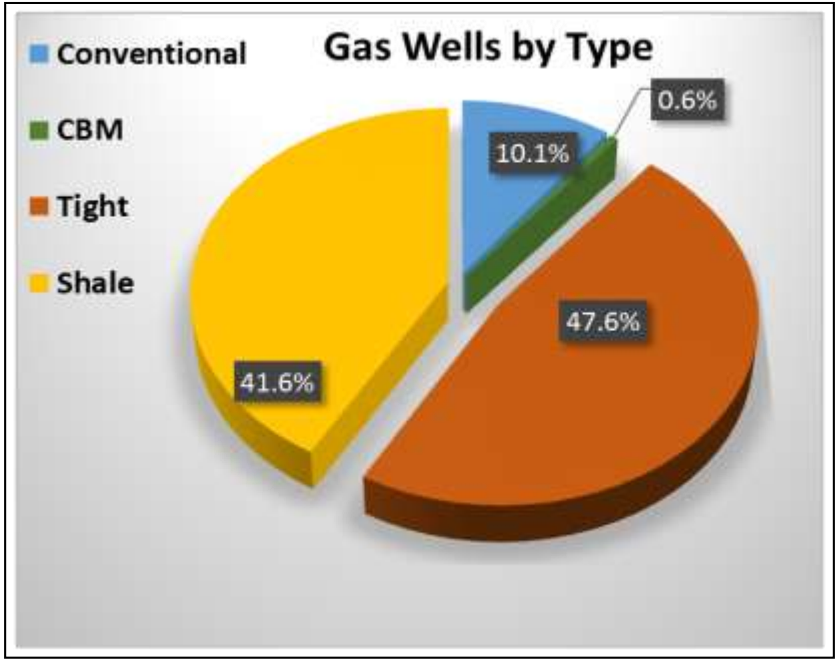
Leading Indicators Characteristics

Organization	Characteristics of Leading Indicators	
API	• Reliable • Repeatable • Consistent	• Meaningful • Appropriate for the intended audience • Easy to use
NSC	• Actionable • Meaningful • Transparent	• Easy to communicate • Valid • Useful
IAEA	• Direct relationship between the indicator and safety • Availability of required data • Unambiguous	• Applied in regular operational activities • Get validated easily • Connected to the cause of a failure

Leading Indicators Types

Organization	Types of Leading Indicators	
API	• Process Hazard Evaluations Completion • Training Completed on Schedule • Procedures Current and Accurate	• Safety Critical Equipment Inspection • Completion of Emergency Response Drills • Fatigue Risk Management
A major oil company	• PHA [Process Hazard Analysis] Recommendation Implementation Overdue • Safety Instrumented Systems (SIS) Functions Disabled • SIS [Safety Instrumented System] Functional Test Overdue	• Investigations • Critical Process Variable Deviations • Open Temporary Leak Repairs • Utilization (Mechanical Utilization) • Overdue training

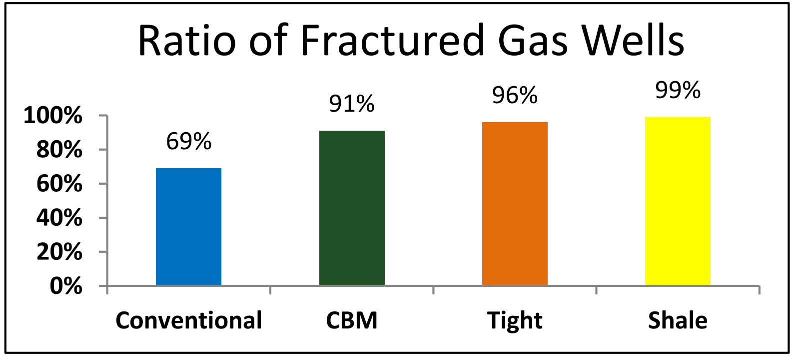
Ratio of Gas Well Numbers for Different Resources



(Shirez et al. 2012)

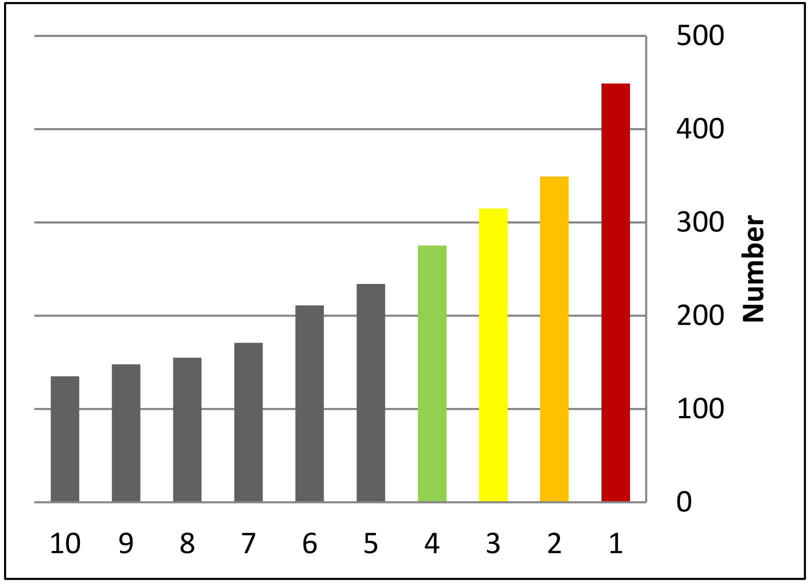
Number of Fractured Wells

Resource	Total Wells	Vertical	Horizontal	Total Fractured
Conventional	536	315	57	370
CBM	33	27	3	30
Tight	2,528	2,054	368	2,427
Shale	2,210	317	1,863	2,188
Total	**5,307**	**2,713**	**2,291**	**5,015**



Top 10 HSE violations (Marcellus Shale - PA)

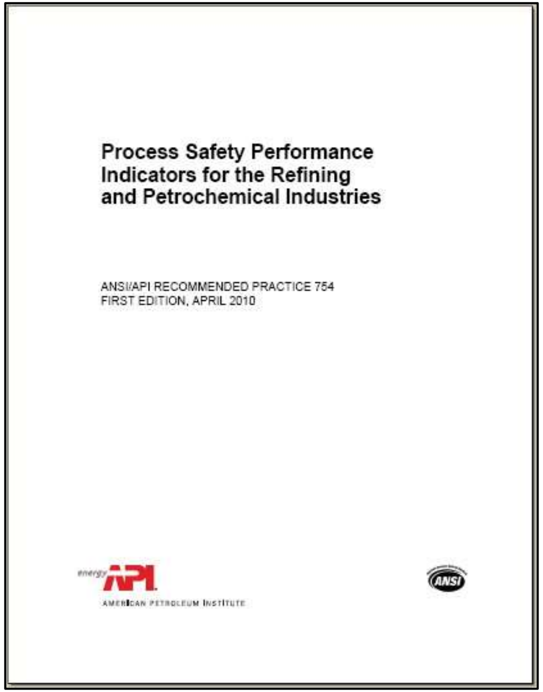
#	Violation Description	Violation Type
1	Failure to properly store, transport, process or dispose of a residual waste.	Environmental Health and Safety
2	O&G Act 223-General. Used only when a specific O&G Act code cannot be used	Administrative
3	Failure to minimize accelerated erosion, implement E&S plan, maintain E&S controls. Failure to stabilize site until total site restoration	Environmental Health and Safety
4	Failure to adopt pollution prevention measures required or prescribed by DEP by handling materials that create a danger of pollution.	Environmental Health and Safety



(Stateimpact 2015)

Leading Indicators: Upstream vs. Downstream

- API Recommended Practice 754: devised for petrochemical and refinery industry
- No such a thing for upstream production
- Customized guidelines must be developed for each field
- Leading indicators can yet be recognized for hydraulic fracturing industry


Process Safety Performance
Indicators for the Refining
and Petrochemical Industries

ANSI/API RECOMMENDED PRACTICE 754
FIRST EDITION, APRIL 2010

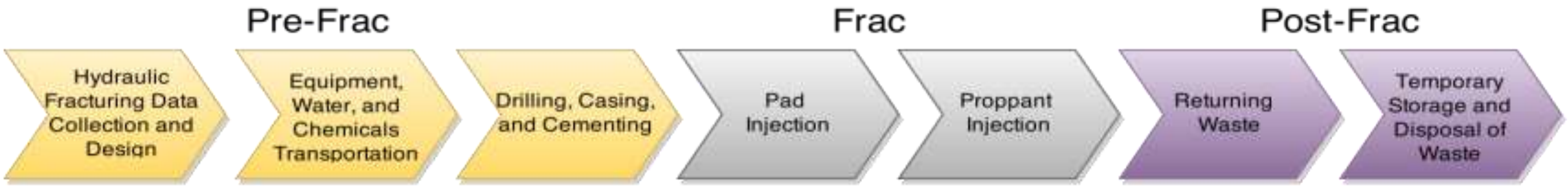
energy API
AMERICAN PETROLEUM INSTITUTE

ANSI

Leading Indicators in Hydraulic Fracturing

Leading Safety Indicators

- Inherently safe design
- Testing and inspection of the equipments
- Technical competence assessment and assurance
- Assessment of the risk of major incidents
- Quality of and adherence to operating procedures
- Blowout precursor (e.g. loss circulation)
- Mechanical integrity
- Capability of the contractor
- Training and developmenet and workers management
- Asset integrity and process safety initiatives
- Fatigue risk management
- Safety culture



- Gaseous emissions (e.g. Methane, H_2S, VOCs, CO)
- Aqueous discharges and quality of the wastewater produced
- Non-aqueous hydraulic fracturing and drilling flluids
- Spills of Chemicals and hydrocarbon (MSDS* centric precautions and health and environmental indicators)
- Silica exposure
- On-site monitoring (water and air samples)

*MSDS: Material Safety Datasheet

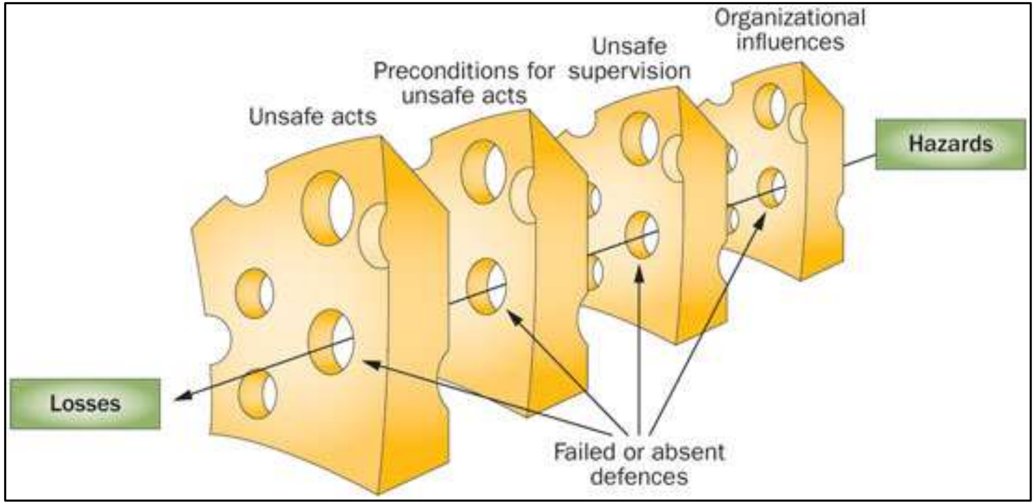
Leading Health and Environmental Indicators

Note: Safety indicators are adapted from different agencies (Listed on table 2).
Environmental and health indicators are adapted from (IOGP 2014).

How to make things better?

- A person may not handle 15-16 things at the same time
- Importance of getting automated and sophisticated: sensors and real-time monitoring
- More research to find the holes

James Reason Swiss Cheese Model



http://www.nature.com/nrurol/journal/v10/n3/fig_tab/nrurol.2013.13_F2.html

Hydraulic Fracturing Incidents: Case-1

- Caddo Parish, LA (2010)
- Striking an unknown gas pocket during initial drilling
- Gas spewed in the air/ infiltrate groundwater
  - 400 residents evacuated
  - Unusable water: not safe to drink, or bathe
- Leading indicators: gaseous emissions and blowout precursors

Lustgarten (2010)

Hydraulic Fracturing Incidents: Case-2

- Dunn County, ND (2010)
- Uncontrolled blowout in the **fifth stage** of a 23 stage hydraulic fracturing operation
- 84,000 gallons of hydraulic fracturing fluid and oil to the surrounding environment
- Reason: Equipment failure
- Leading Indicators:

Mechanical integrity tests prior and during the operation

Donovan (2013)

Hydraulic Fracturing Incidents: Case-3

- Clearfield County, PA (2010): Well blowout (returned fluid & drilling waste)
- Malfunction of a blowout preventer
- Operator failed to contain contaminants within the wellbore for 18 hours
  - Gas, drilling waste, and 35,000 gallons of flow-back fluids in a tributary that feeds into a high quality cold water fishery
- Lack of accurate inspection/ Absence of properly trained employees

Malone (2010)

Hydraulic Fracturing Incidents: Case-4

- Billings County, ND (2013): Well blowout

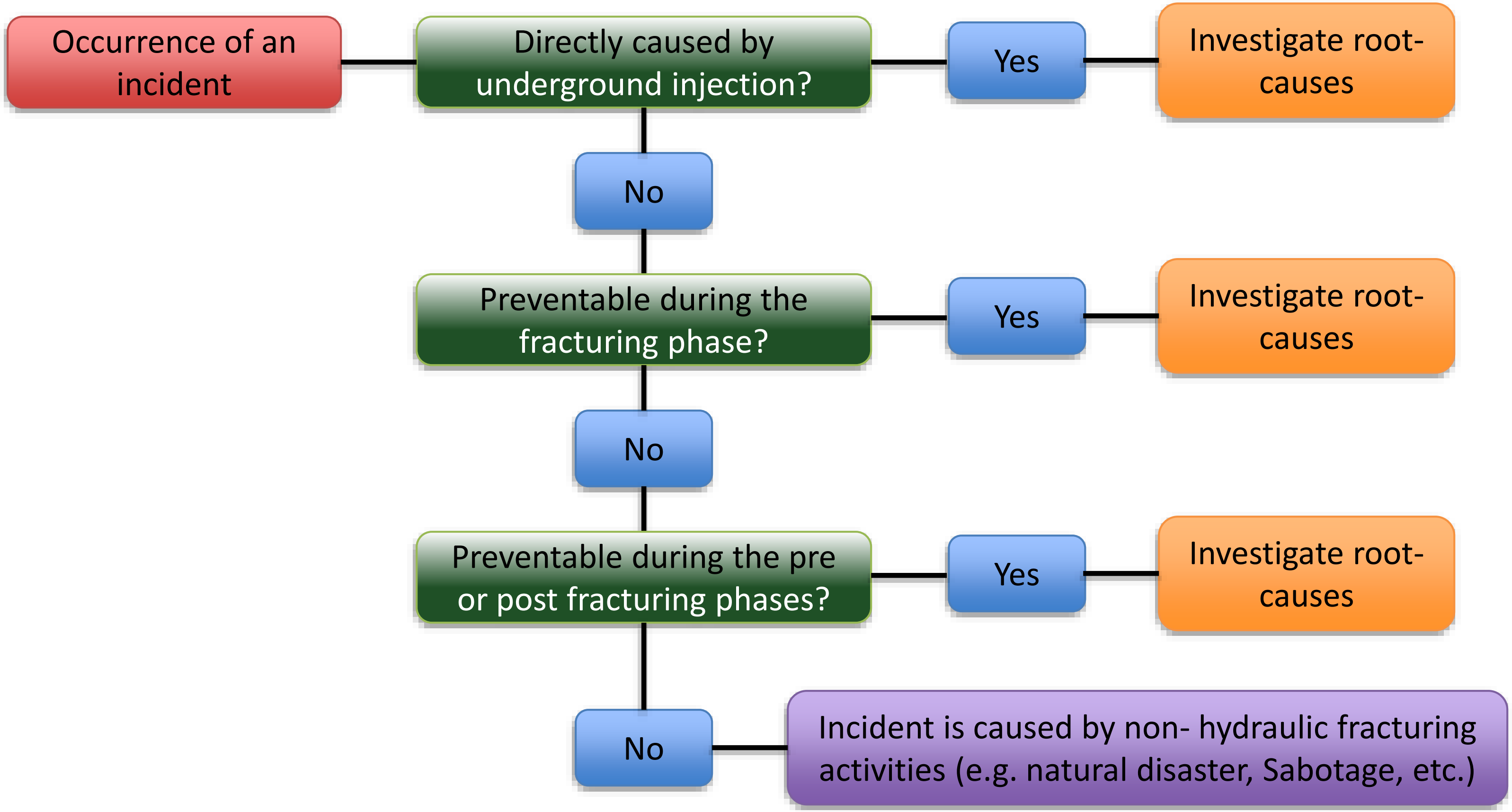
Sontag and Gebeloff (2014)

- Compromised plugged packer during the casing stage, resulting in the release of subsurface pressure
- 100 barrels of oil and 4,025 barrels of brine (173,250 gallons of pollutants) were released in 2 days

Hydraulic Fracturing Incidents: Case-4

- The blowout cause was “an irresponsible supervisor’s callous disregard of” its “well-established standard operating procedures”.
  - human factors
- Human factors could have been mitigated by the proper use of model simulations, equipment training, and safety meetings.

Proposed Steps for Incident Classification



New Ideas

- Extensive data collection
- Application of data analysis new techniques and soft computing methods (i.e. Machine Learning)
- Goals:
  - ✓ To help develop leading indicators to classify incidents
  - ✓ To flag situations with higher risk

Construction Industry Example

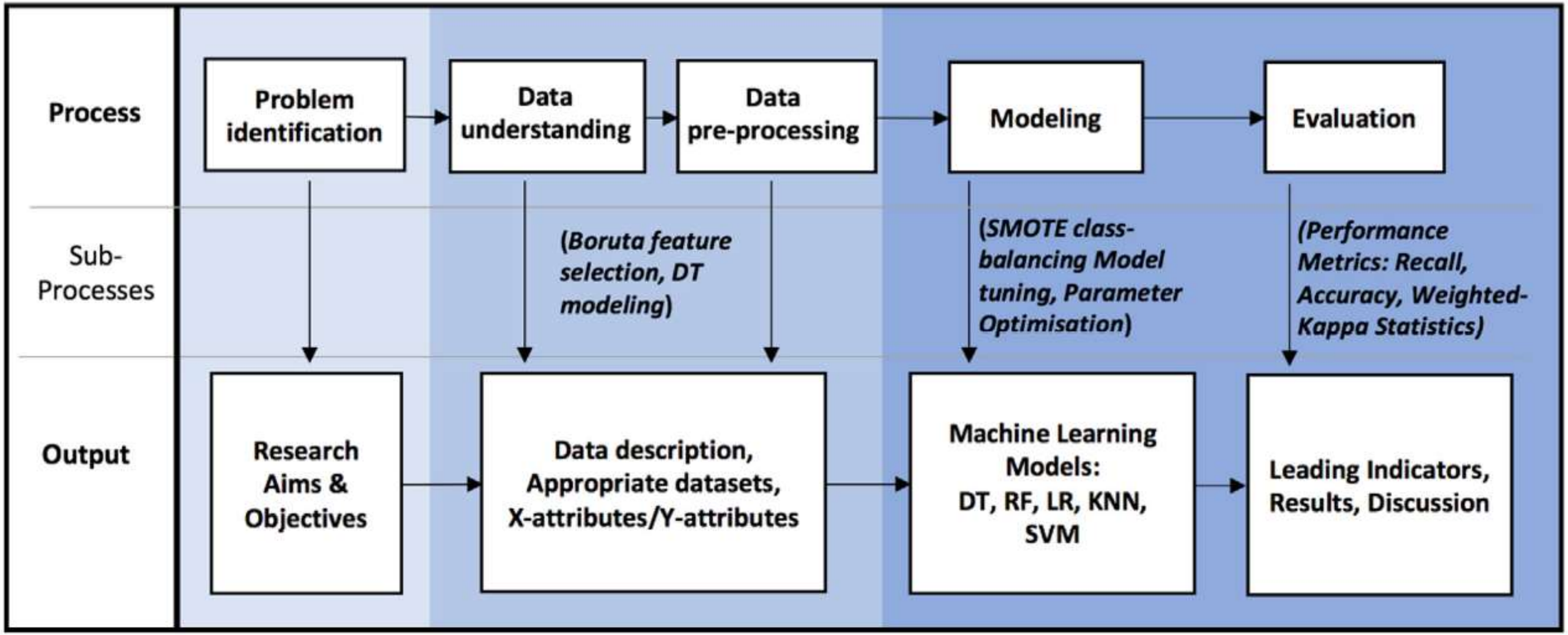
- Poh, C.Q.X., "*Safety leading indicators for construction sites: A machine learning Approach*," Automation in Construction (2018), https://doi.org/10.1016/j.autcon.2018.03.022

- Construction: One of the most dangerous industries for workers

- Data used: Safety inspection records, accident cases, and project-related data

- the ML-predicted leading indicator: "No Accident", "Minor Accident" and "Major Accident" (low, medium and high risk of accidents)

Construction Industry Example – Research Design



Concluding Remarks

- Time to wake up to take the people's confidence
- Learning from other industries is a must: Leading and lagging indicators
- Vital to know the potential safety and environmental hazards for each operation (Flowchart) / Rigid guidelines may not work
- The best way to answer public's concerns: ensuring the safety of the operations: Automation! People make mistakes
- Pumping money into research development!
- Monitoring and data collection: great tools in developing indicators

Thank you for your attention!
Questions?