NIOSH Oil & Gas Extraction Sector Program: Overview of Safety and Health and Exposure Assessment Research

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Disclaimer

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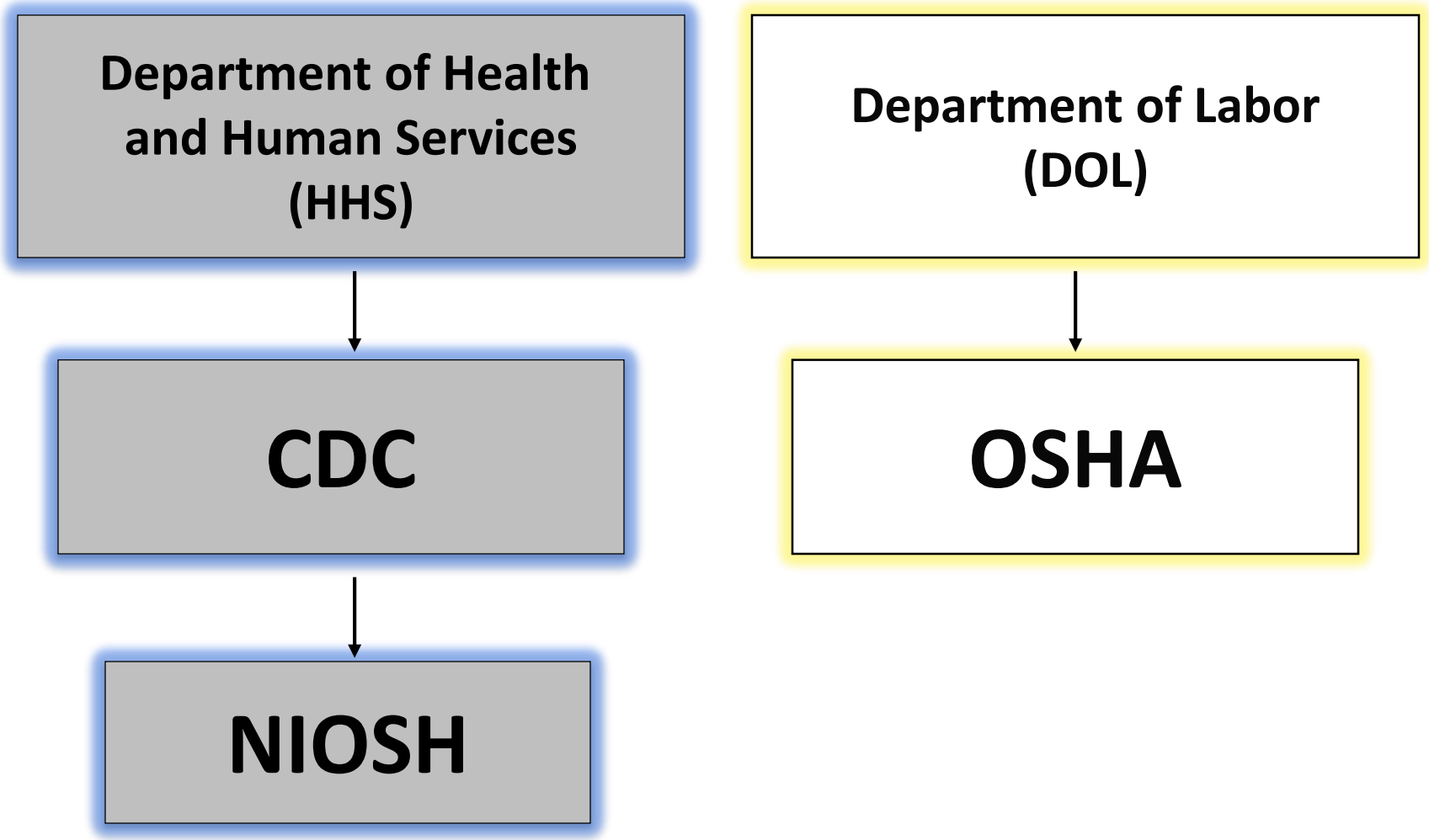
What is NIOSH?

- NIOSH is the National Institute for Occupational Safety and Health
- U.S. federal agency that conducts research and makes recommendations in order to prevent worker injury and illness
- Main objective: protect the safety and health of the nation's 155 million workers
    - Estimated cost of work-related fatalities, injuries, and illness in 2007 was $250 billion in medical costs and productivity losses

Occupational Safety & Health Act 1970



What drives NIOSH research?

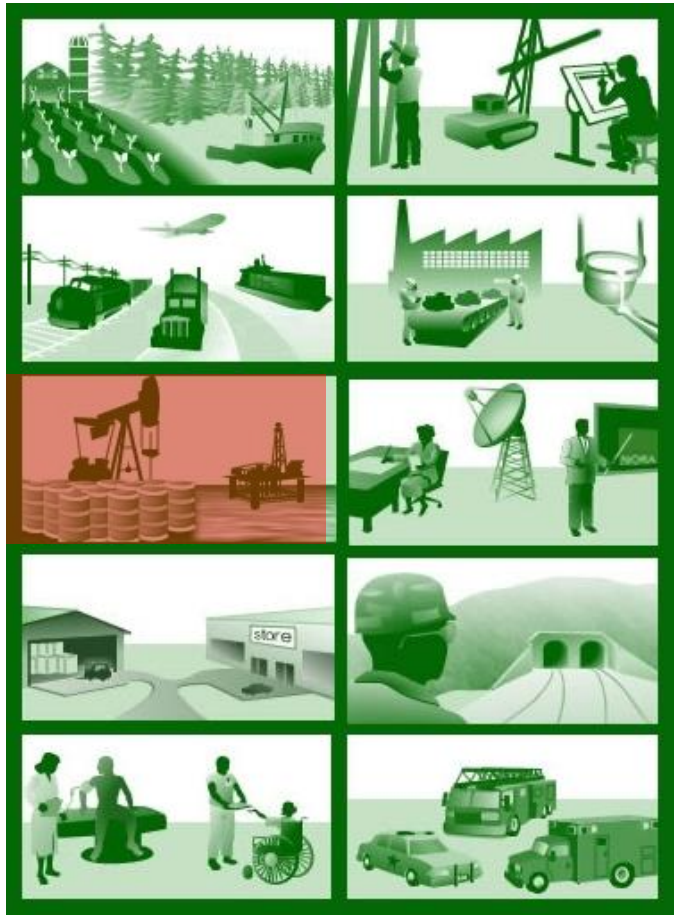
National Occupational Research Agenda

- a partnership program to stimulate innovative research and improved workplace practices since 1996
- diverse parties collaborate to identify the most critical issues in workplace safety and health
- partners then work together to develop goals and objectives for addressing these needs

Priorities influenced by:

- The number of workers at risk for a particular injury or illness
- The seriousness of a hazard or problem
- The chance that new data or approaches can make a difference

Sectors

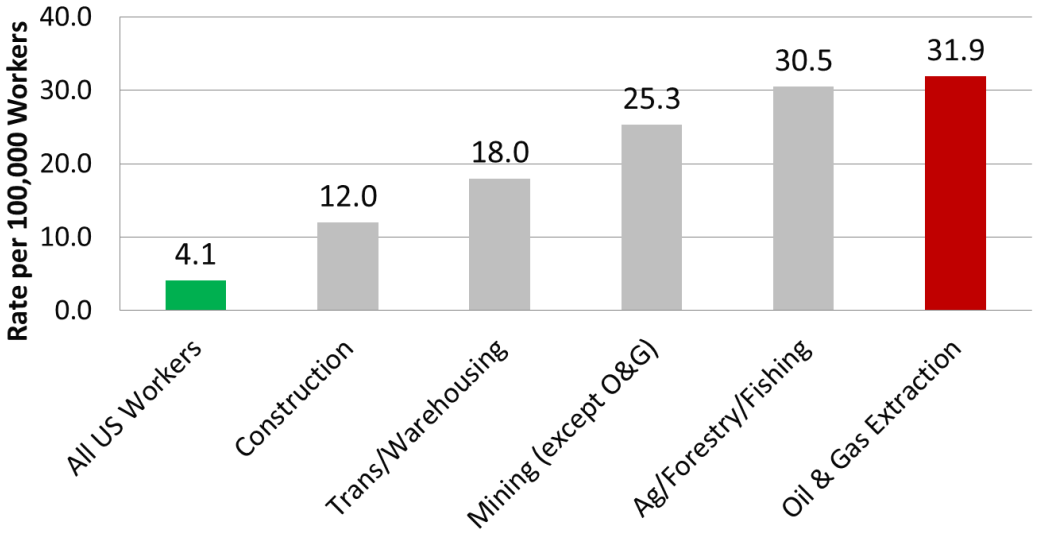


NORA research goals are organized into 10 programs representing different industry sectors:

- Agriculture, Forestry and Fishing
- Construction
- Healthcare and Social Assistance
- Manufacturing
- Mining
- Public Safety
- Services
- Transportation, Warehousing and Utilities
- Wholesale and Retail Trade
- **Oil and Gas Extraction**

The Beginning of NIOSH Program: 2005-2007

- In August 2005, U.S. Department of Labor's Bureau of Labor Statistics (BLS) asked CDC to investigate a 15% increase in fatalities among oil and gas extraction workers
- 85 fatalities in 2003 and 98 fatalities in 2004
- Dr. John Howard, Director of NIOSH, appointed two scientists from the Alaskan office to find out why this was occurring



Establishment of the NORA Oil and Gas Council

Early Partners

NIOSH identified and invited safety and health professionals from industry, government, and academia to join the **National Occupational Research Agenda (NORA) Oil and Gas Extraction Sector Council**

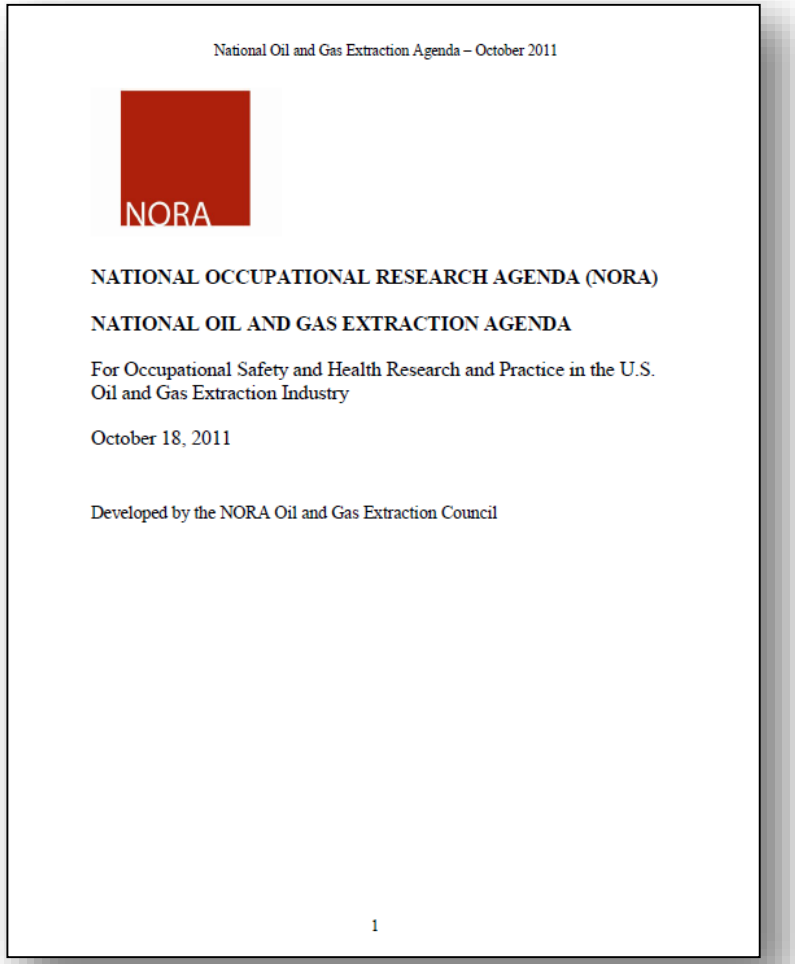
Pre-Council Meeting

- Held in February 2008
- Goals: to outline subsector issues and working groups, identify key stakeholders for possible participation, plan future meetings
- Participants began to develop a list of research issues that would be considered by the council in the development of the Oil and Gas Extraction Subsector Council Strategic Plan:

NORA O&G Sector Meetings

- First full meeting occurred in July 2008
- Primary objective was to formulate an outline of possible safety and health research topics
- Group continued to grow, adding new members over the years
- Published a strategic plan outlining research priorities for both NIOSH and the O&G stakeholders in 2011

NORA National Oil and Gas Extraction Agenda



National Oil and Gas Extraction Agenda – October 2011

NORA

NATIONAL OCCUPATIONAL RESEARCH AGENDA (NORA)

NATIONAL OIL AND GAS EXTRACTION AGENDA

For Occupational Safety and Health Research and Practice in the U.S. Oil and Gas Extraction Industry

October 18, 2011

Developed by the NORA Oil and Gas Extraction Council

1

Strategic Goals

By 2020:

- Reduce the occupational fatality rate in the oil and gas extraction industry by 50%
- Reduce the occupational motor vehicle fatality rate in the oil and gas industry by 50%
- Reduce the fatality rate due to contract injuries in the oil and gas extraction industry by 50%
- Reduce the rate of non-fatal occupational injuries in the oil and gas extraction industry by 50%
- Identify hazards, characterize risk, and prevent chemical exposures which could lead to occupational illness in workers in the oil and gas extraction industry

NIOSH OIL & GAS EXTRACTION SAFETY & HEALTH PROGRAM

NORA

NORA Projects

PHP Projects

Chemical Exposures to Oil & Gas Workers (EE, JS, MB)

Contact Injury Prevention Project (PS)

Motor Vehicle Best Practices in Oil & Gas (KR)

PPE Use in O&G: Seat Belts & Fall Protection (NM)

Preventing Fires & Explosions in Oil & Gas (JB)

Chemical Exposures to O&G Workers (MB)

Rig Move Safety for Oil & Gas Workers (EC)

Injuries in the Offshore Oil & Gas Industry (RH)

Preventing Falls in Oil & Gas (PS)

Projects

2007 2008 2009 2010 2011 2012 2013 2014 2015

Outputs

SPE Article: Working Hard to Work Safely

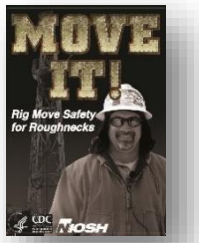
SPE Article: Fatalities by Company Type and Size

MMWR: Fatalities Among O&G Workers

Fact Sheet: Chemical Exposures to O&G Workers

Take Pride in Your Job: Seat Belts & Fall Protection

Move It! Rig Move Safety for Roughnecks



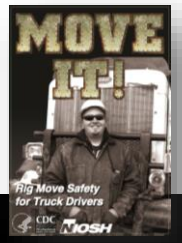
SPE Article: Mortality Statistics for the US Upstream Industry

Well Servicing: Fatal Injuries in the Upstream O&G Industry

ASSE Professional Safety: Effective Training, A Case Study from the O&G Industry

NIOSH Science Blog: Worker Exposures to Crystalline Silica during Hydraulic Fracturing

Move It! Rig Move Safety for Truckers



Synergist: Keeping Up with the Oil and Gas Rush

SPE Article: Review of the Literature: MV Safety Practices

Well Servicing: Understanding Silica Exposure Risks and Controls

JOEH Article: Occupational Exposures to Respirable Crystalline Silica during Hydraulic Fracturing

NIOSH Science Blog: Worker Fatalities during Flowback Operations

NIOSH Science Blog: Worker Exposures to Volatile Chemicals during Oil and Gas Extraction Flowback and Production Testing Operations

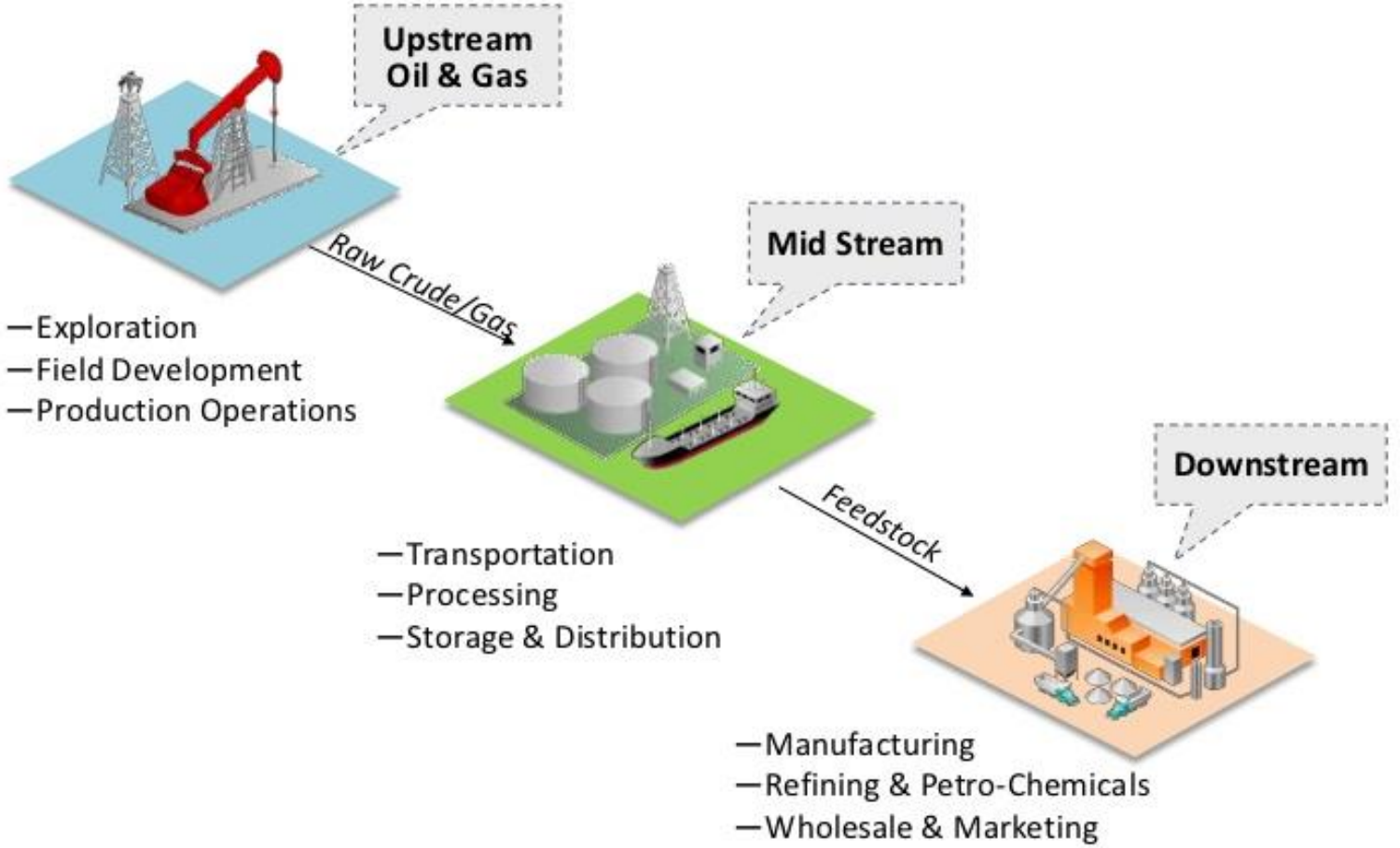
JOEH Case Study: Chemical Exposure Risks during Flowback Operations in Unconventional Oil and Gas Extraction

Fatalities in Oil and Gas: O&G Database

DVDs

Publications

The Global Oil & Gas Value Chain

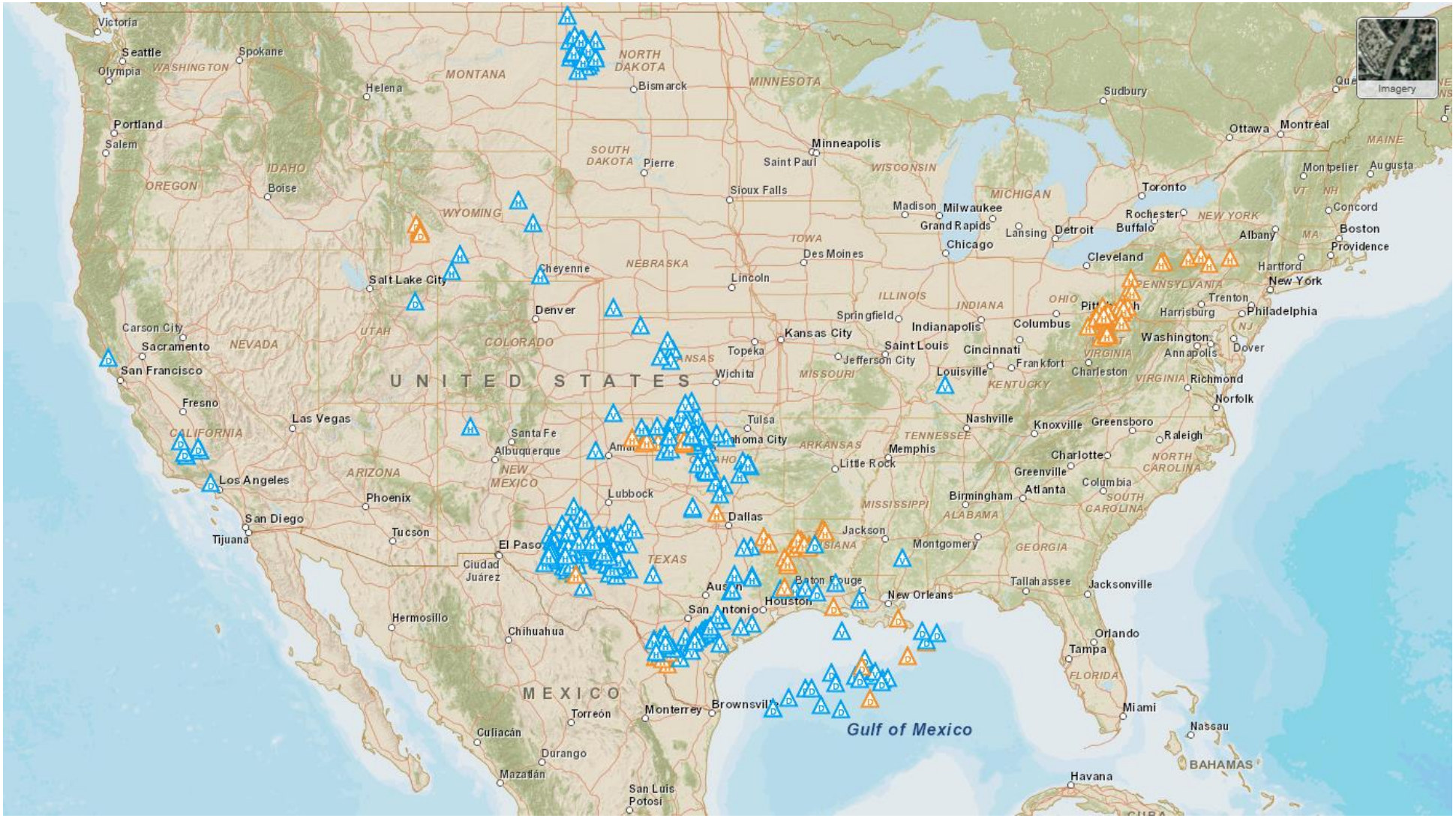


—Exploration
—Field Development
—Production Operations

—Transportation
—Processing
—Storage & Distribution

—Manufacturing
—Refining & Petro-Chemicals
—Wholesale & Marketing

Major Oil and Gas Production Areas



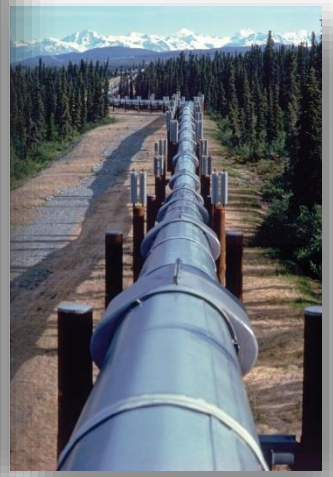
Upstream has the Highest Fatality Rate in the U.S. Oil & Gas Industry, 2014

Upstream

36% of total workers
Fatality Rate = 22.9

Midstream

17% of total workers
Fatality Rate = 4.1



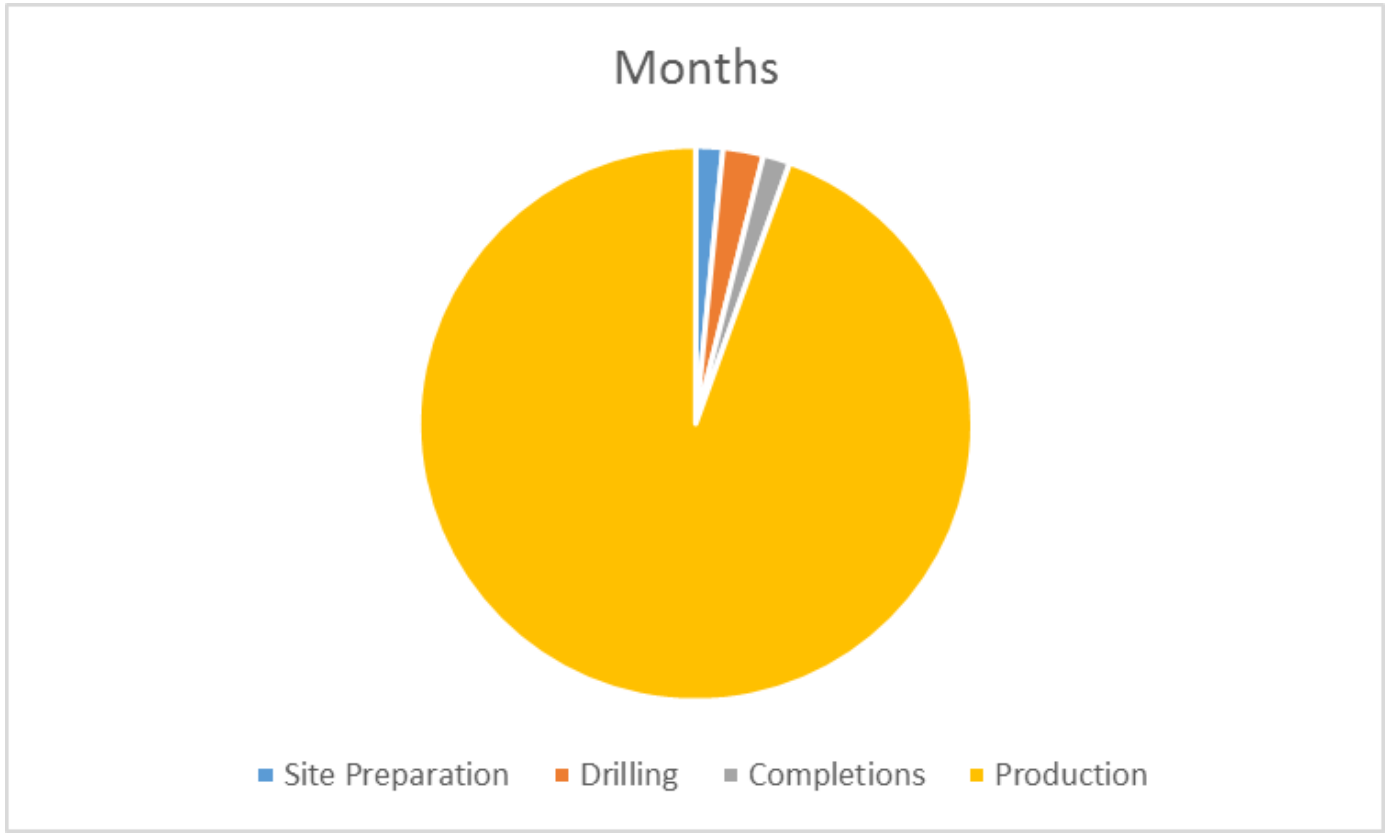
Downstream

60% of total workers
Fatality Rate = 4.2

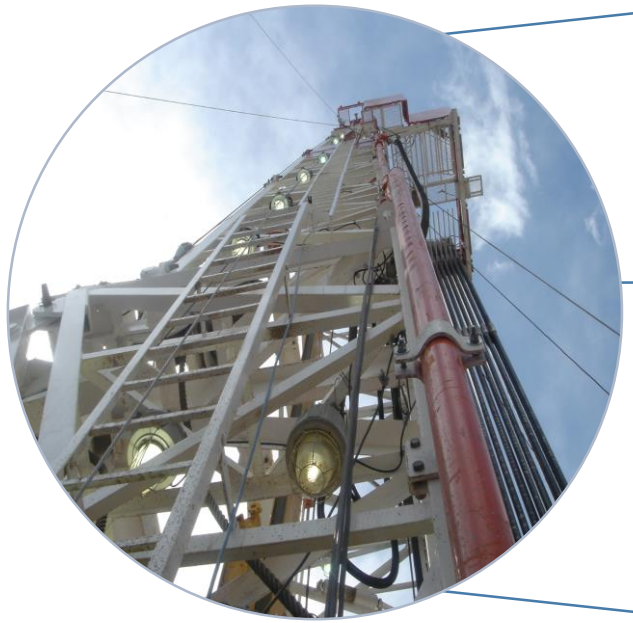
Upstream Oil and Gas Exploration & Production

1. Exploration, leasing, etc.
2. Road & site preparation
3. Drilling, casing, cementing wellbore to TD
4. Completions (hydraulic fracturing)
5. Well testing, connection to grid
6. Servicing, re-stimulation, other work

Duration of Activities



The U.S. Oil and Gas Extraction Industry



Oil and Gas
Extraction Industry

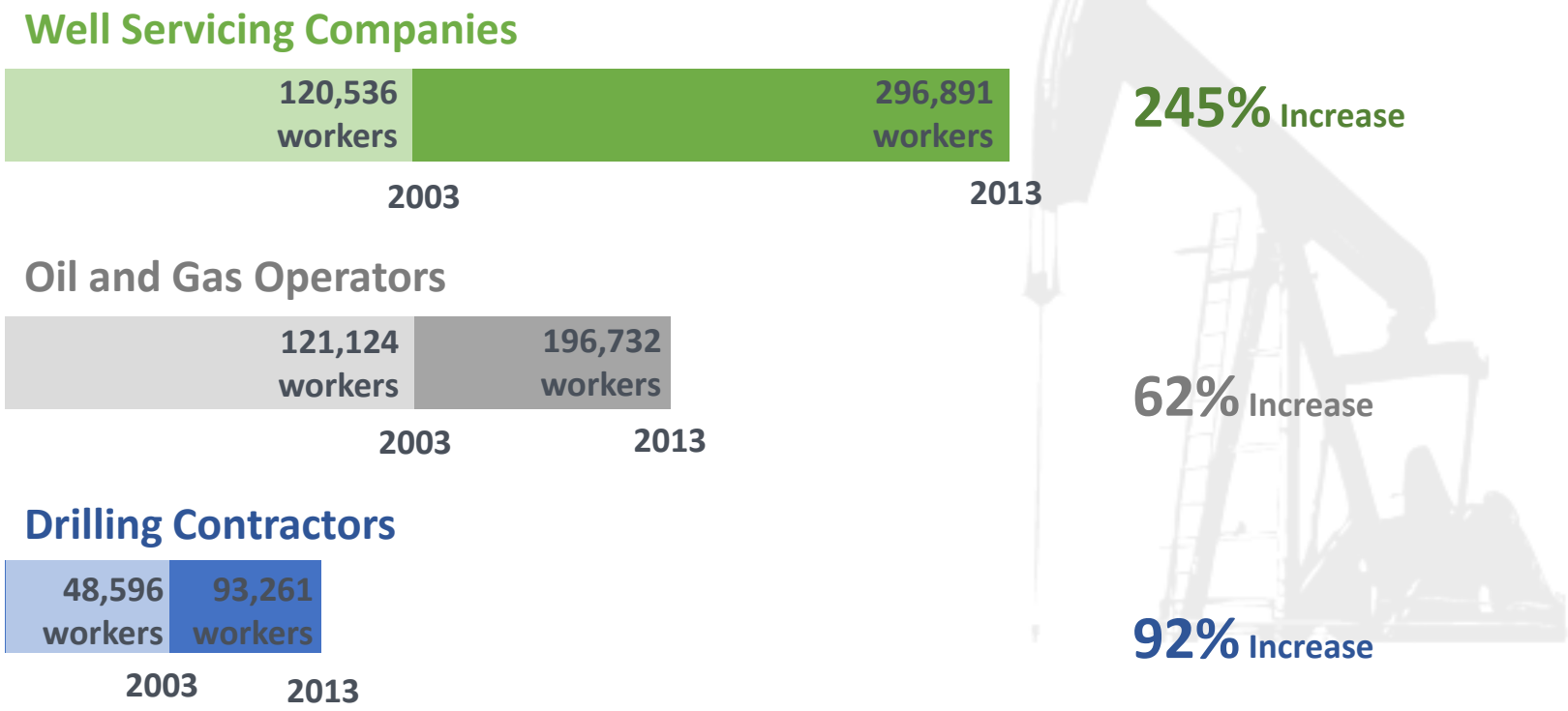
Operators

Drilling
Contractors

Well
Servicing
Companies

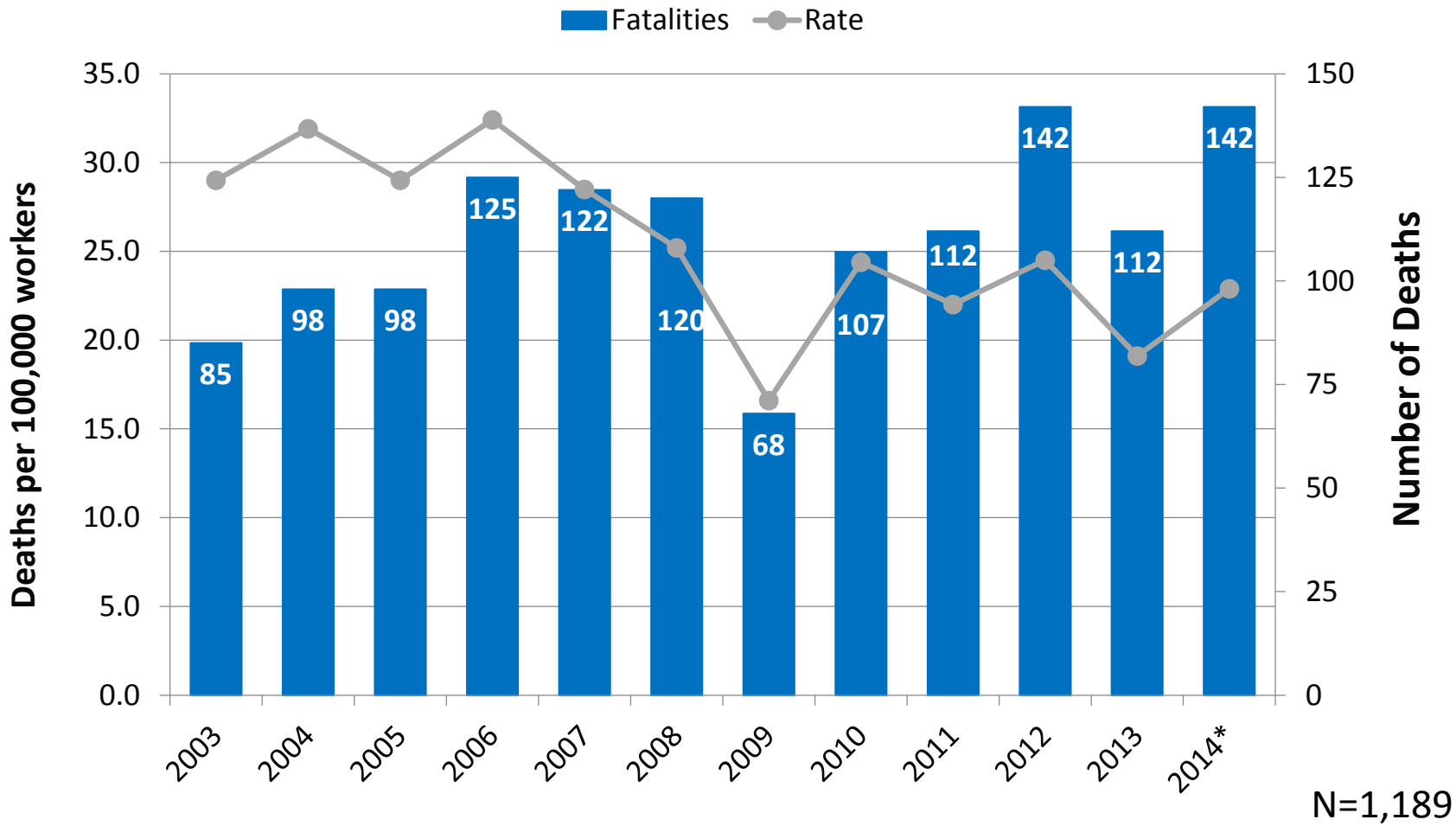
Industry Growth

The oil and gas workforce doubled and the number of drilling rigs increased 71% from 2003-2013.



Number and Rate of Fatal Work Injuries

U.S. Oil & Gas Extraction Industry, 2003-2014



Note: Fatality counts from BLS Census of Fatal Occupational Injuries. Worker Estimates from BLS Quarterly Census of Employment and Wages (2013). Rate per 100,000 workers per year. Includes NAICS 211, 213111, 213112. *Data for 2014 are preliminary.

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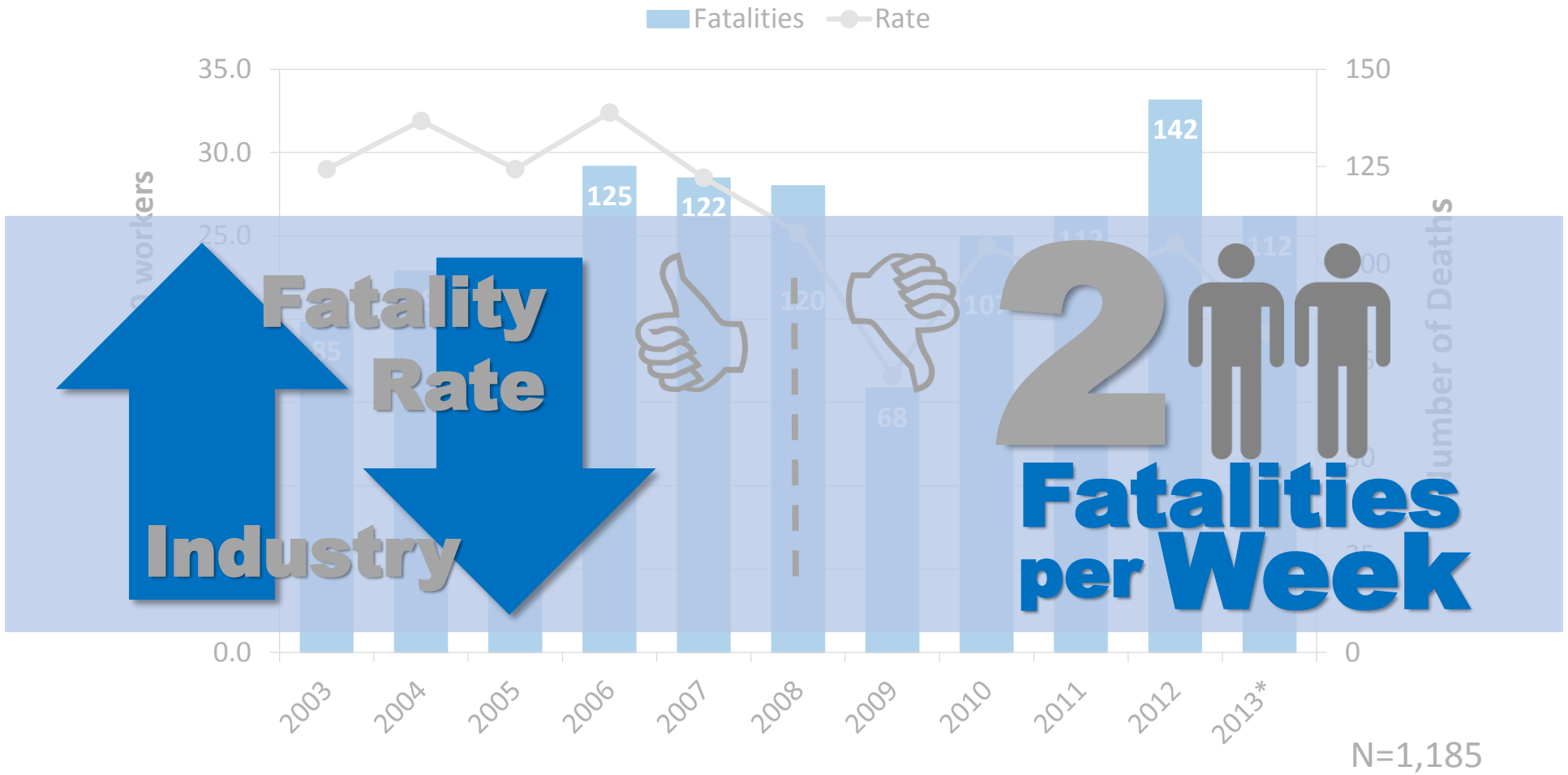

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Trends in Fatality Rate by Company Type, 2003-2013

Oil and Gas Operators

Fatalities

58%

Statistically Significant

Well Servicing Companies

Fatalities

33%

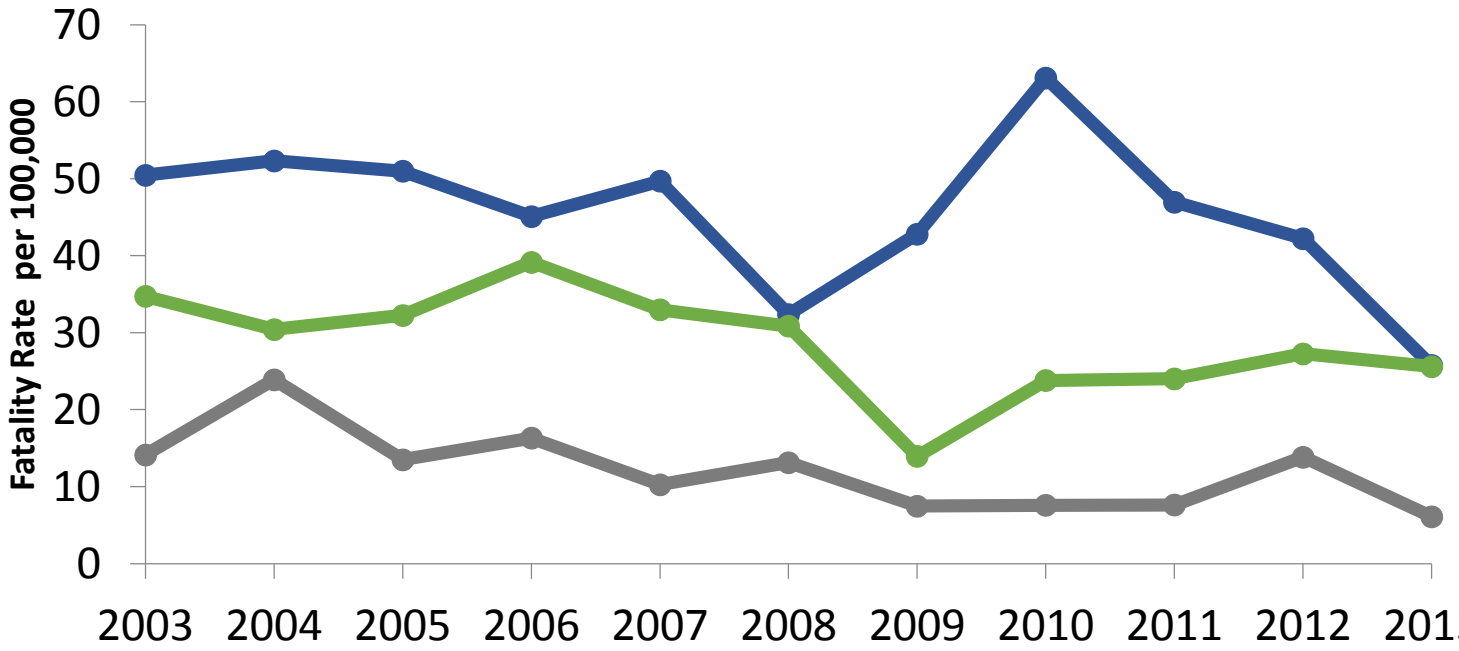
Statistically Significant

Drilling Contractors

Fatalities

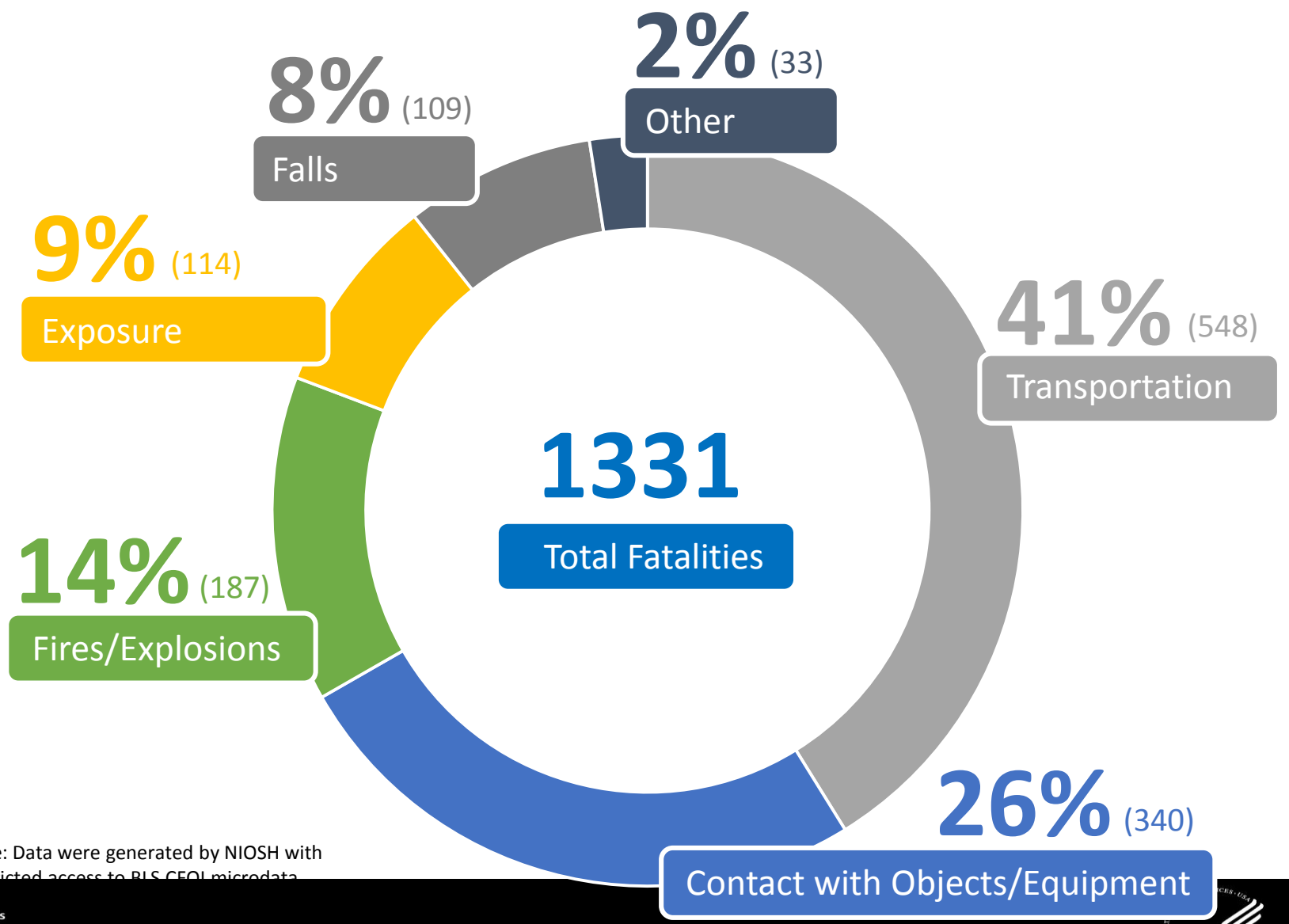
27%

Not Statistically Significant



Most Frequent Fatal Events

U.S. Oil & Gas Extraction Industry, 2003-2014

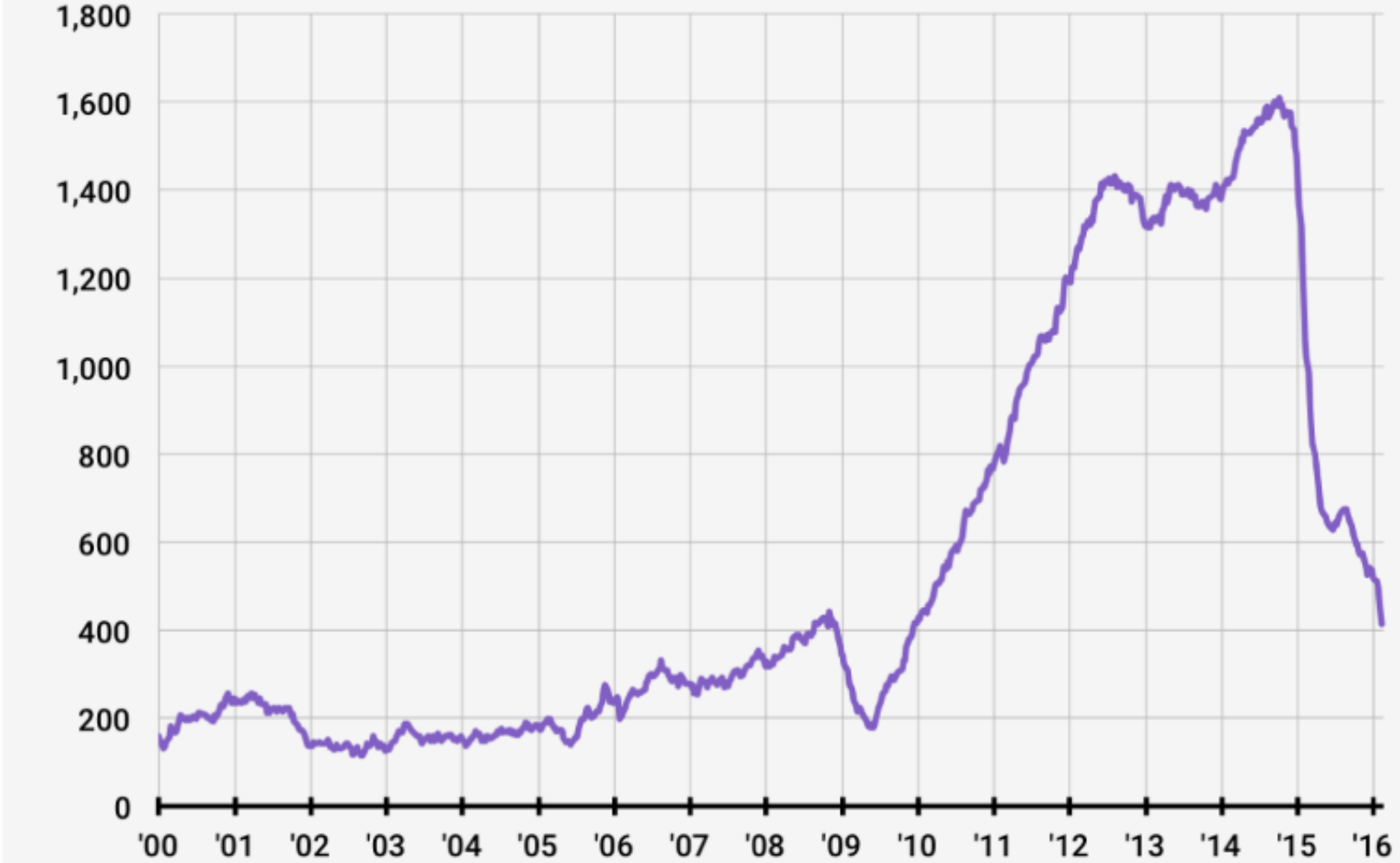


Note: Data were generated by NIOSH with restricted access to BLS CFOI microdata

Non-fatal Injuries in Exploration and Production

- Most segments of oil and gas extraction report a lower nonfatal injury rate than the average for all private industry
- In 2010 the estimated rate of nonfatal work-related injuries in oil and gas extraction (NAICS 211) was:
  - 1.2 per 100 full-time workers over all
  - 1.9 for workers in support activities for oil and gas extraction (NAICS 213112)
  - 3.3 for drilling oil and gas wells (NAICS 213111)
- The annual rate for all private industries during the same year was 3.5 nonfatal injuries per 100 full-time workers

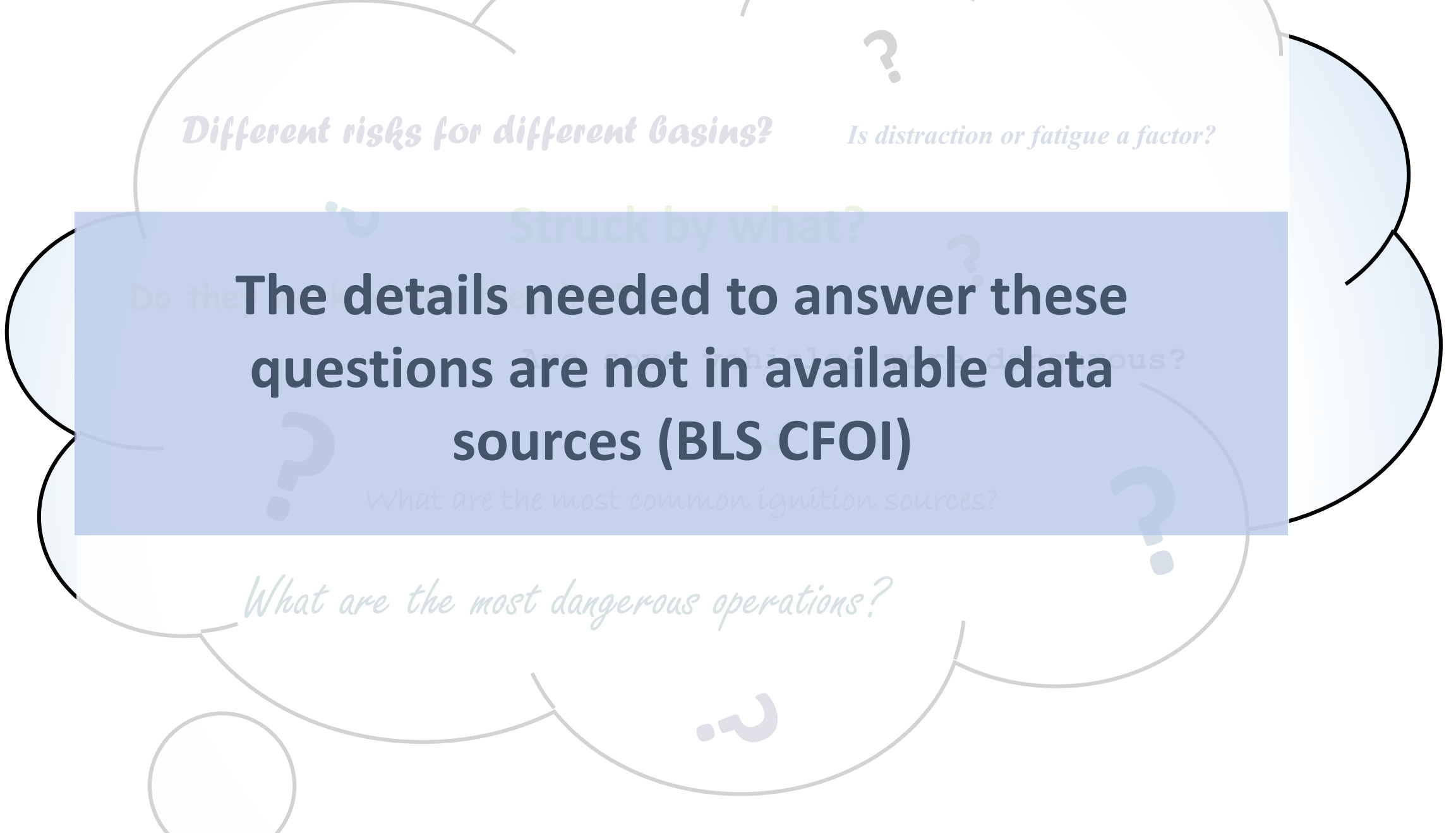
US OIL RIG COUNT



SOURCE: Baker Hughes

BUSINESS INSIDER
Andy Kiersz/Business Insider


Different risks for different basins?
Is distraction or fatigue a factor?
Struck by what?
Do they work where they live?
Are some vehicles more dangerous?
What are the most common ignition sources?
What are the most dangerous operations?



The details needed to answer these questions are not in available data sources (BLS CFOI)

Fatalities in Oil and Gas (FOG) database

New internal database collecting detailed information about oil and gas worker fatalities in the U.S.

Includes

All identified fatal events to U.S. oil and gas extraction workers

- Land-based
- Offshore
- Common O&G NAICS
- Uncommon O&G NAICS
- Motor vehicle incidents
- Non-traditional commutes
- Cardiac events

Excludes

Midstream, downstream, non-fatal injuries

Limitations

Off-site motor vehicle incidents, work-related chronic illness

Data Sources

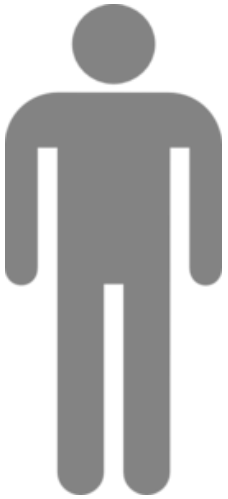
OSHA, media, crash reports, autopsy reports, industry etc.

Fatalities in Oil and Gas (FOG) database

50 Variables per Incident

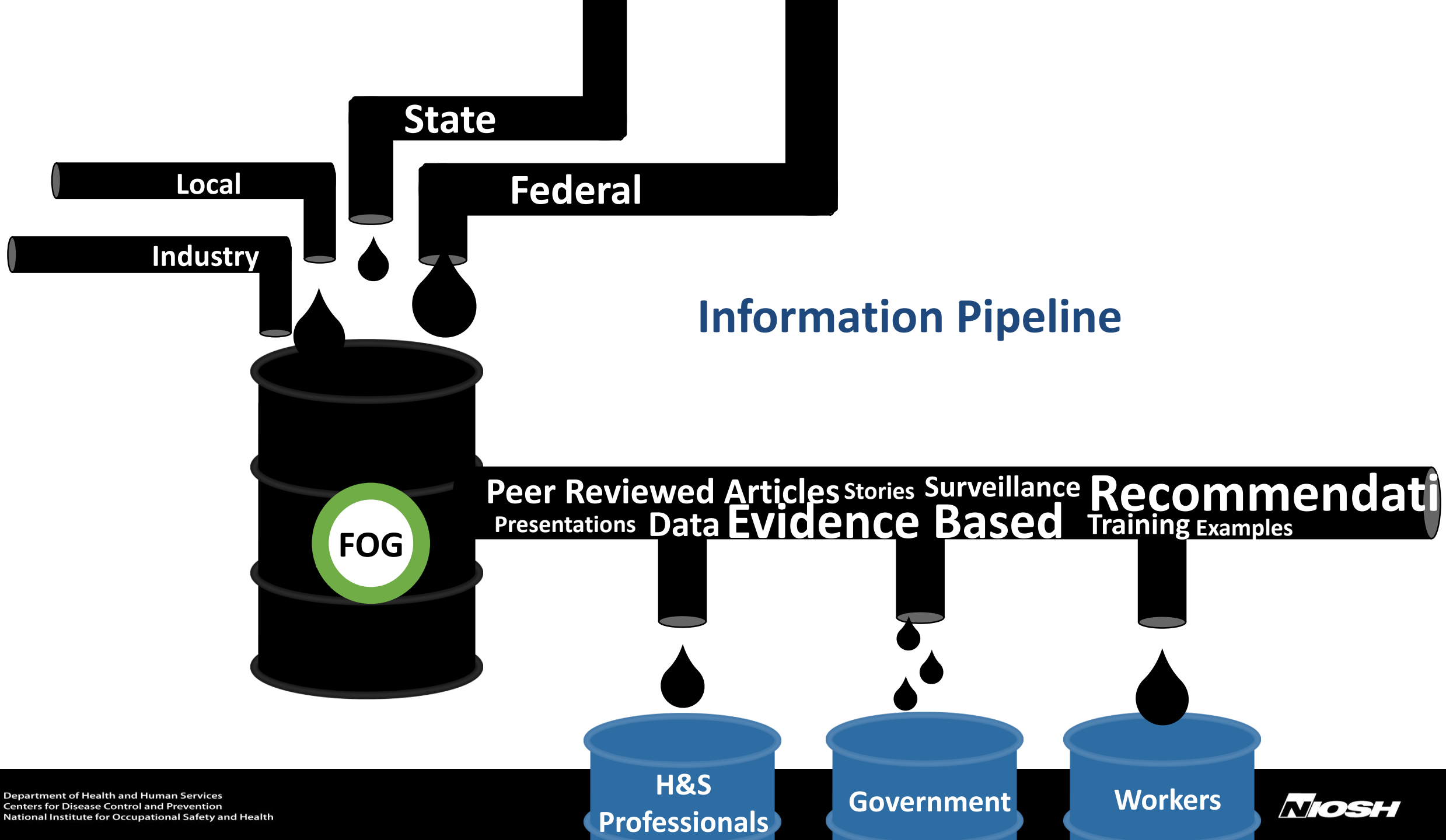
- ✓ Operation
- ✓ Basin
- ✓ Fatigue Related
- ✓ Weather Related
- ✓ Offshore Incidents

FOG collects the details that are missing from other data sources



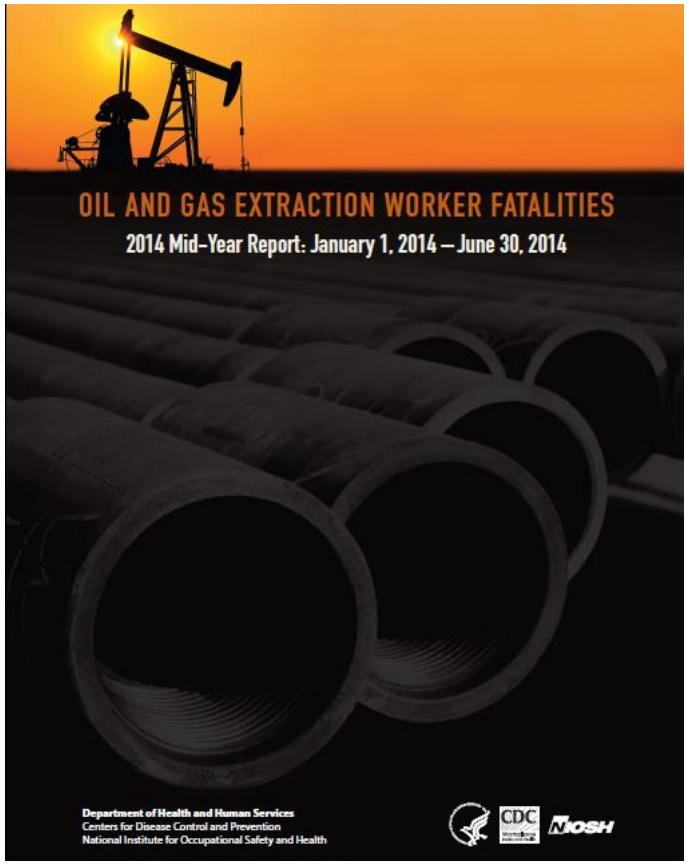
41 Variables per Worker

- ✓ Race
- ✓ Occupation
- ✓ Years in Oilfield
- ✓ English as a Second Language
- ✓ Task


State
Local
Federal
Industry
Information Pipeline
FOG
Peer Reviewed Articles
Stories
Surveillance
Recommendati
Presentations
Data
Evidence Based
Training
Examples
H&S Professionals
Government
Workers

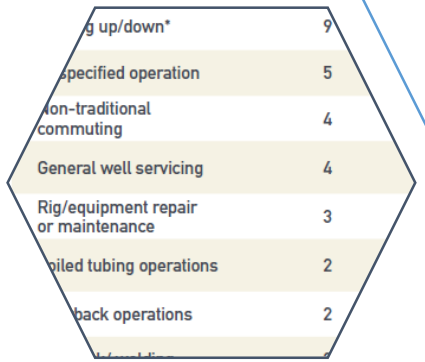
First FOG NIOSH Numbered Publication

2014 Mid-Year Fatality Report

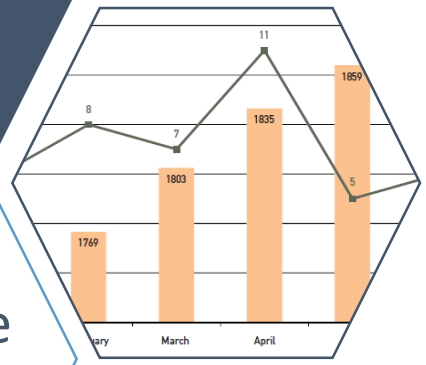


Maps

Fatalities by Operation



Descriptive Statistics



Narratives

On the Horizon

Special topic reports

- Fires/Explosions associated with tanks
- H_2S exposure
- Dropped tubulars

Time frame reports

- Full year reports
- Multi-year reports (5 year report)

Queriable FOG system

Oil and Gas Extraction Worker Survey

Worker Exposure Assessment

Based on worksite operations and chemicals in the industry, workers have potential risks for exposures to multiple chemical hazards

Field Studies- identify and characterize workplace exposures and evaluate their significance.

- Become familiar with process operations
- Perform the preliminary, qualitative survey
- Perform workplace monitoring (quantitative evaluation)
- Interpret the sampling results and communicate with stakeholders
- Develop controls if needed
- Re-evaluate to determine effectiveness of controls

Exposure Hazards

Not an all-inclusive list

Silica

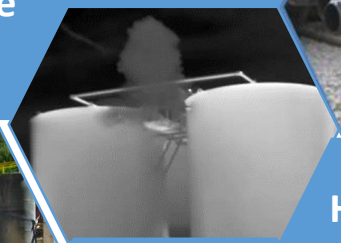
Diesel particulate matter

Volatile Organic Compounds (BTEX)

NORM and T-NORM

Biocides (aldehydes, quaternary, others)

Oil mists



Alcohols (Methanol)

Hydrogen sulfide (H_2S)

Metals

Acids & Bases

Polyaromatic Hydrocarbons

NIOSH FIELD STUDY STRATEGIES

- Focus on process or activity
  - Drilling, Completions, Production, Service
- Focus on exposure hazard
  - Chemical: Silica, Hydrocarbons, Diesel Exhaust etc
  - Physical: Noise, Heat/Cold, NORM
- Focus on emerging issue identified by surveillance
- Focus on worker exposures by production area
- Development and evaluations of controls

NIOSH Field Laboratory

2015 Bravo Star Trailer

- 7 x 12 interior space
- Weatherized
- Heating/AC
- Can operate with generator power or supplied shoreline power

Finally, after 2 years!

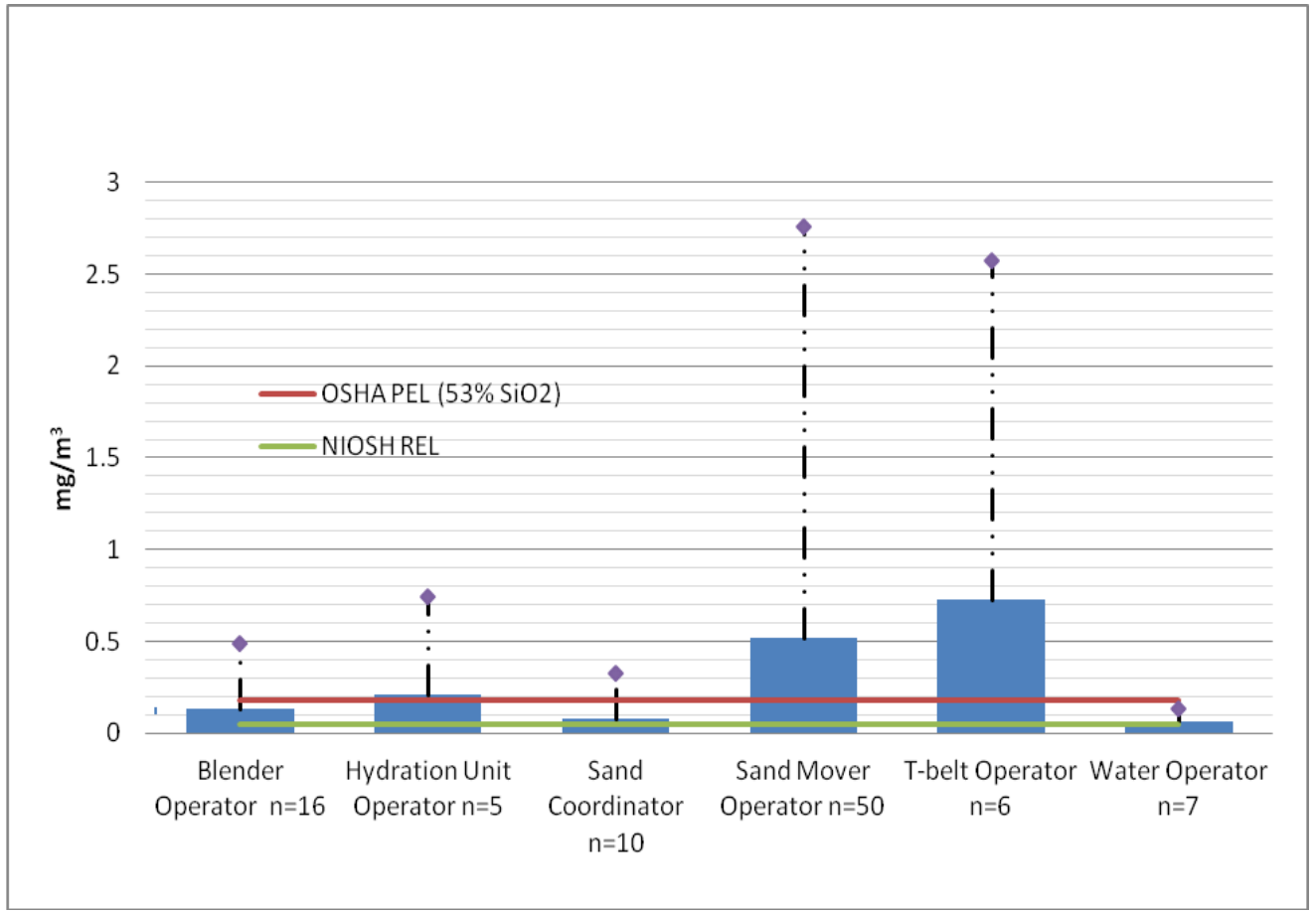
Methods Used

- Standard Industrial Hygiene Methods
  - NMAM and OSHA Numbered Methods
  - Personal and Area Samples
- Direct Reading Methods
  - Real Time Instruments, Meters and Monitors
  - Video Exposure Monitoring
- Biological Monitoring
  - Measure Internal Exposures/Effects by Breath, Urine

Focus on Process-Completions

Primary Health Hazard- Exposure to Respirable Silica during Hydraulic Fracturing

Exposure comparisons by job title

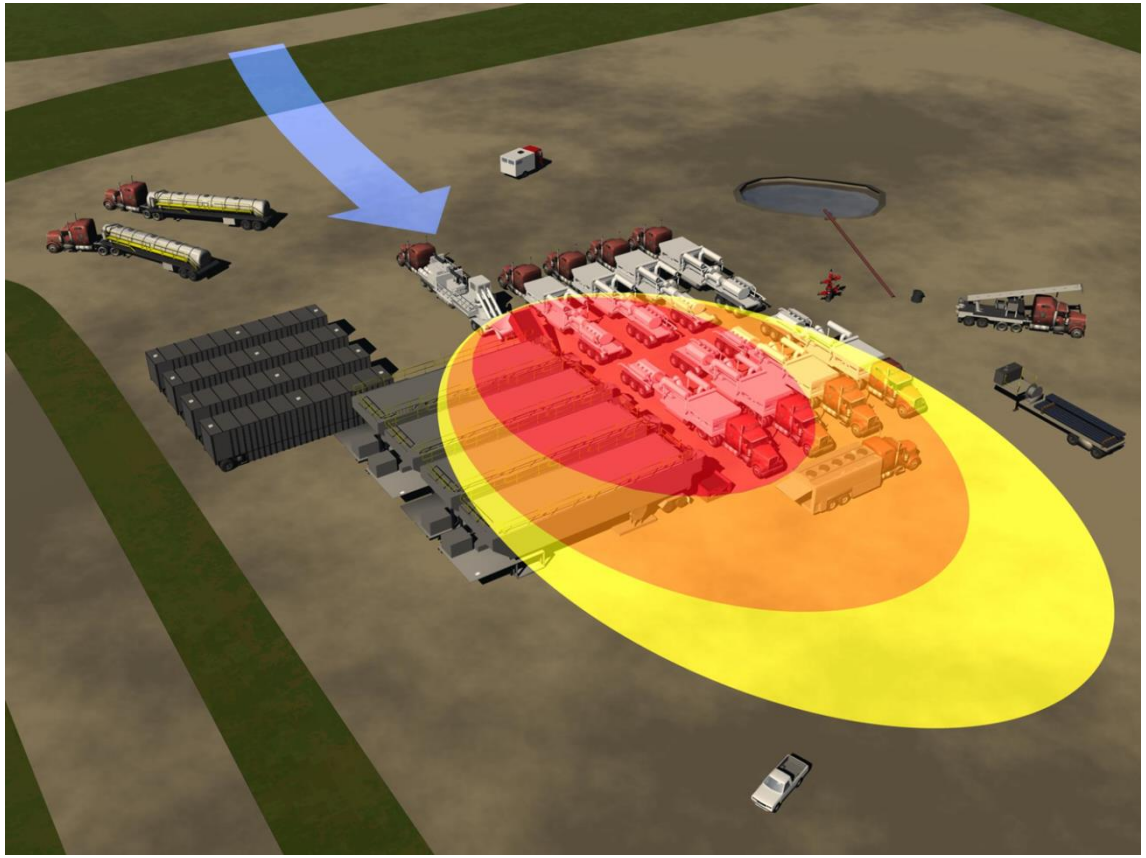


Point Sources of Respirable Crystalline Silica Release

Eight (8) primary points of dust release or generation from completions equipment or workplace operations

1) Dusts ejected from thief hatches on top of the sand movers during refilling operations
2) Dust ejected and pulsed through side fill ports on the sand movers during refilling operations
3) Dust generated by on-site truck vehicle traffic including sand trucks and crew trucks, the release of air brakes on sand trucks, and by winds
4) Dust released from the transfer belt under the sand movers
5) Dusts created as sand drops into, or is agitated in the blender hopper and on transfer belts
6) Dust released from operations of transfer belts between the sand mover and the blender
7) Dust released from the top of the dragon's tail on sand movers
8) Dust deposited on and released from workers coveralls

Respirable Silica Exposure Zones



Maximum respiratory protection

Moderate respiratory protection

Avoid area during sand transfers and pumping

Impact of NIOSH RCS Study

- First study to identify RCS hazard during hydraulic fracturing
- OSHA-NIOSH Hazard Alert
- Industry formed RCS Workgroup
- JOEH article most downloaded of 2013
- Wide array of new, improved controls implemented

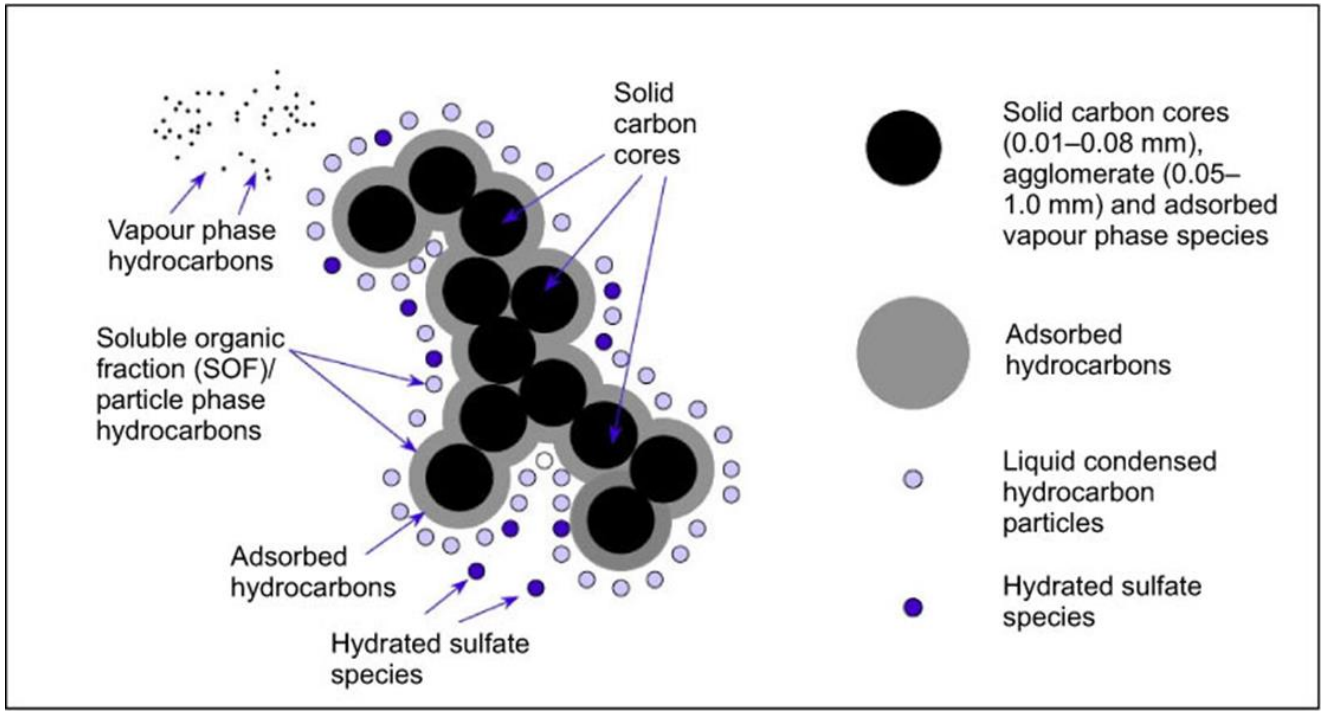
Focus on Hazard- Diesel Particulate

Image courtesy of Jeff Swensen for the New York Times.

What is Diesel Particulate Matter?

The adsorbed compounds comprise 15% to 65% of the total particulate mass and includes compounds such as polycyclic aromatic hydrocarbons, many of which are possibly carcinogenic

Diesel particulate matter is highly respirable (typically less than 2.5 micrometers) and can reach the gas exchange regions of the lungs



Health Effects from DPM exposure

- Depends on how long one is exposed and magnitude of exposure
- Eye and nose irritation
- Throat irritation with cough
- Exacerbation of pre-existing respiratory conditions: bronchitis, asthma, etc.
- Headaches
- Dizziness
- Cardiovascular disease
- Cancer
  - International Agency for the Research of Cancer considers DPM to be a human carcinogen (Group 1)
  - NIOSH considers DPM to be a potential occupational carcinogen
    - Although excess cancer risks for workers exposed to diesel exhaust has not yet been quantified, the probability of developing cancer should be reduced by minimizing exposure

Where can Diesel Particulate Matter (DPM) Be Found on Oil and Gas Sites?

- Diesel powered engines can be found all over sites
  - Diesel powered earth-moving equipment
  - Drilling rigs
  - Wireline crews
  - Blender trucks and pumps
  - Diesel Sand movers and transport (T) belts
  - Water transport systems
  - Fuel Delivery Trucks
  - Diesel-driven generators
  - Specialty crew: equipment for rig moving, coiled tubing, etc.

NIOSH Study

- Combination of data from preliminary oil and gas hazard assessments and Field Effort to Access Chemical Exposures in Oil and Gas Extraction Workers (2008-2012)

- 103 full shift air samples
  - 48 Personal Breathing Zone
  - 55 Area
  - Analysis by NMAM 5040
    - DPM as elemental carbon by Thermal Optical Analysis
- States
  - Colorado
  - North Dakota
  - New Mexico
  - Texas
- Site types
  - Completions Hydraulic Fracturing (56/103 or 54%)
  - Drilling (31/103 or 30%)
  - Servicing (16/103 16%)

Summary Results

- 23 Samples were below the limit of detection
- For 80 samples with reported values:
  - Mean= 16.1 Standard Deviation= 14.2 Range= 2-68 µg/m^3

<u>By Activity</u>

- Completions Hydraulic Fracturing
  - Mean= 13.6 Standard Deviation= 13.4
    Range= 3-52 µg/m^3
- Drilling
  - Mean= 7.4 Standard Deviation= 5.3
    Range= 2-18 µg/m^3
- Servicing-Other
  - Mean= 7.5 Standard Deviation= 3.4
    Range= 2-14 µg/m^3

Summary Continued

- **21 of 103 (20%) samples exceeded the California Department of Health Services OEL of 20µg/m³ (TWA for EC)**

- **4 PBZ samples of 48 (8%) total PBZ samples**

  - Water Transfer Operator 52 µg/m³
  - Chemical Operator 41µg/m³
  - T-belt operator 28 µg/m³
  - Sandmaster Operator 22 µg/m³

- **17 area samples of 55 total area (31%) samples**

Examples

Blender trucks and cabs	21-68 µg/m³
Mud tanks and pumps	22-40 µg/m³
Rig Floor	47 µg/m³
Driller station on rig	38 µg/m³
Containment pit pump	29 µg/m³
Control stations for Sand movers	27-28 µg/m³

Focus on An Emerging Hazard – Tank Gauging

Using FOG to Identify Fatalities

- In 2013, NIOSH contacted by Dr. Bob Harrison regarding 2 deaths where inhalation of petroleum hydrocarbon gases and vapors suspected.
- NIOSH/OSHA reviewed fatalities (2010-2014) in FOG and monitored deaths closely.
- Published 1st Science Blog in May 2014 (following 2 more deaths).

Worker over Open Hatch

Fatality Case Definition

- Non-traumatic
- Worker in proximity to a known and concentrated source of hydrocarbon gases and vapors. (open hatch)
- Hydrogen Sulfide (H_2S) was ruled out.
- Not confined space.
- Not fires/explosions.
- Case by Case Review conducted by OSHA/NIOSH.

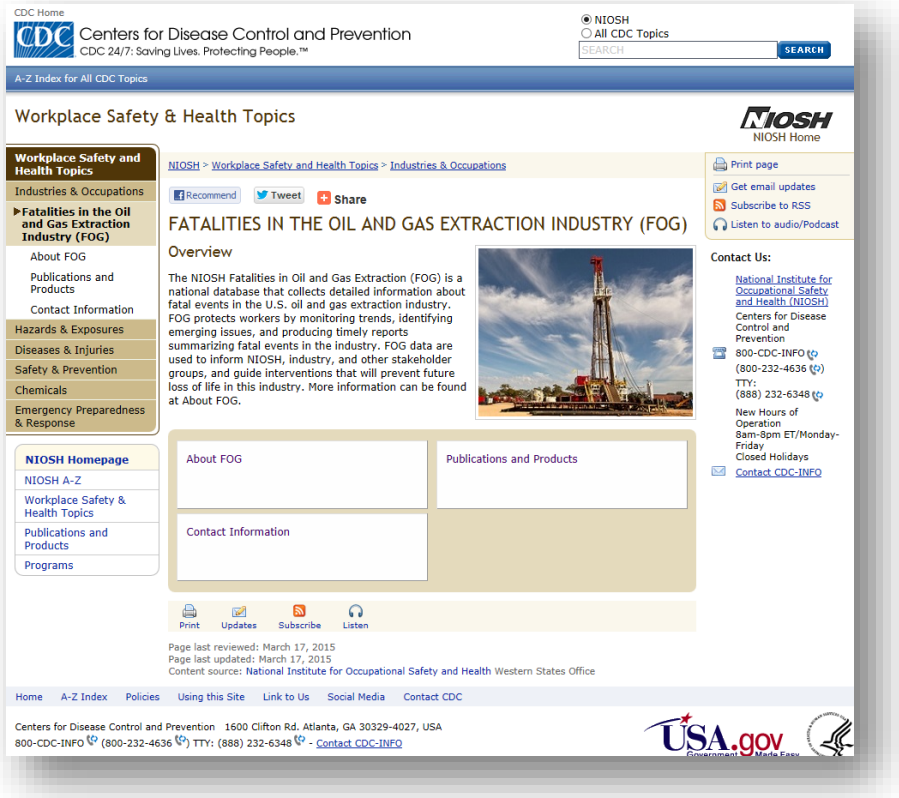
Fatalities Associated with Manual Gauging, Thieving, Fluid Handling

Nine (9) worker deaths where inhalation of petroleum hydrocarbons was likely factor.

- All occurred at production tanks.
- 5 fatalities occurred during thieving (collecting a sample) by fluid haulers.
- One employee was wearing 4-gas monitor, reported 6.5% O2..
- One had sought medical evaluation for dizziness, etc. a few weeks prior.

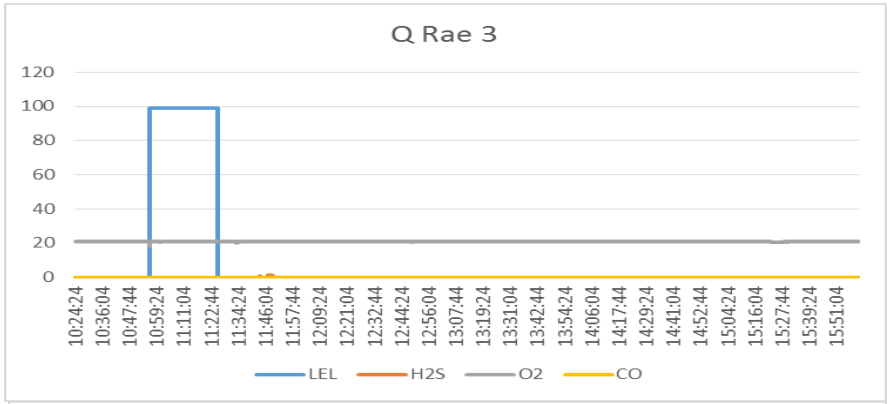
NIOSH FOG Report and Science Blog Update

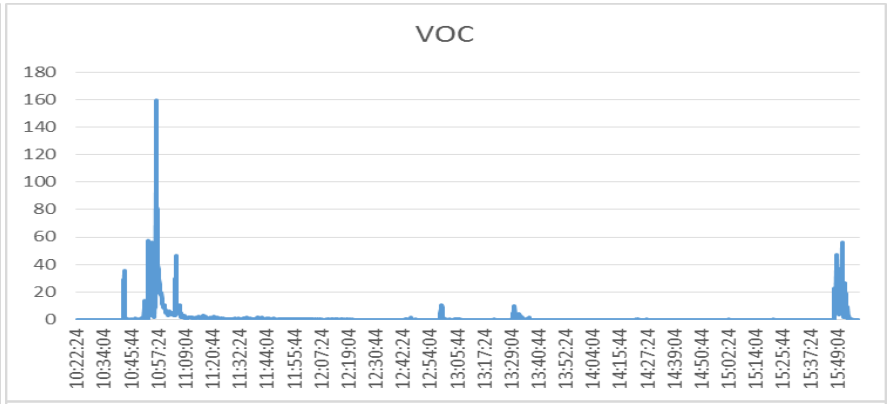
Suspected Inhalation Fatalities Involving Workers during Manual Tank Gauging, Sampling, and Fluid Transfer Operations

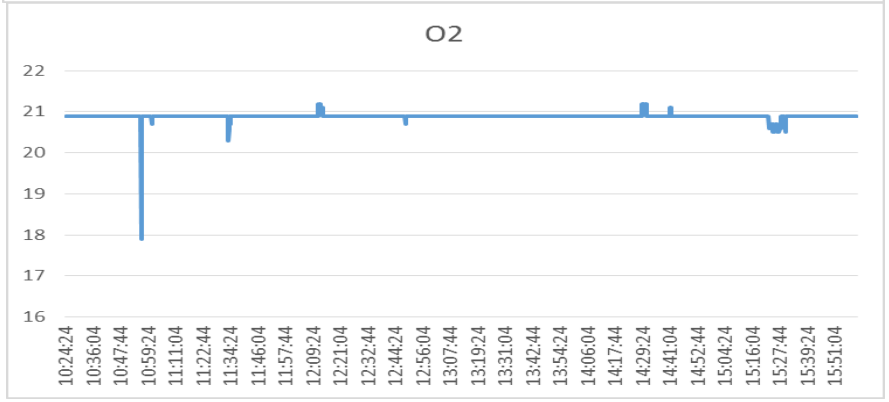


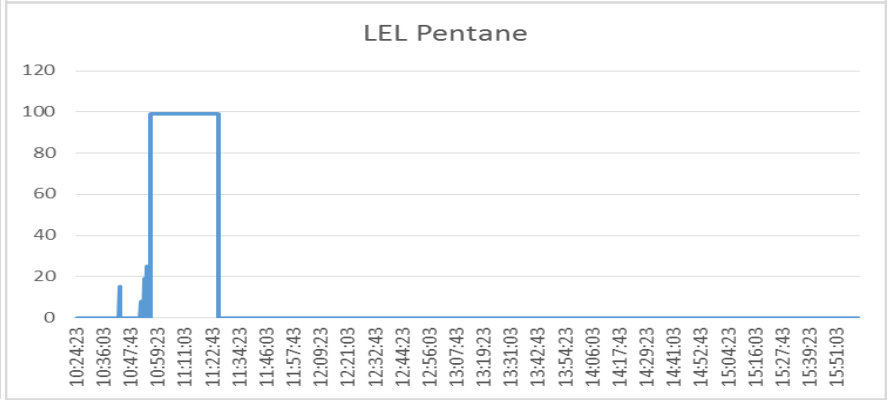
www.cdc.gov/niosh/topics/fog/publications.html

Direct Reading Instruments
Qualitative Characterization of Tank Release









Evaluating Rapid Releases of Hydrocarbon

- Exposure assessments designed to measure gas and vapors released in plumes and during very short worker tasks
  - Non-traditional IH assessment methods
  - Grab Samples
  - PEAK, STEL, IDLH assessments
  - Real-time GC as well as GC/MS analysis

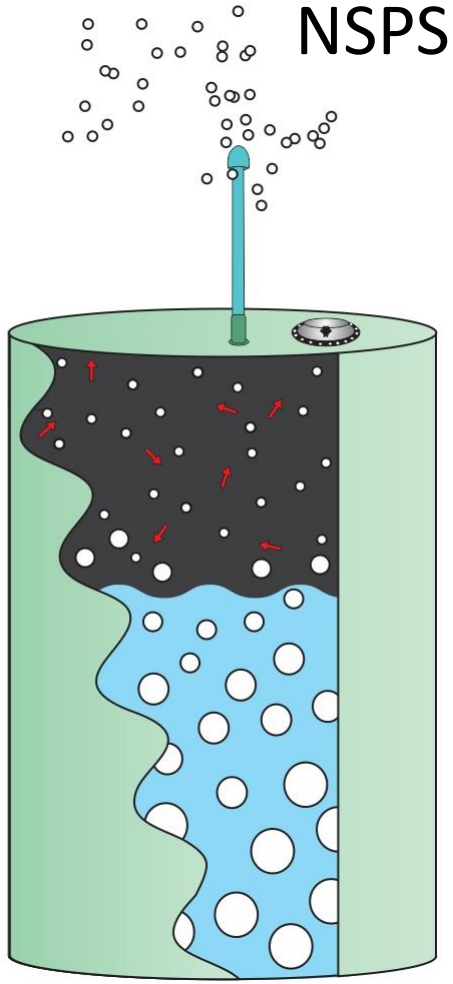
Grab Samples 0.5 meters above hatch

Analyte	Concentration Range	IDLH (ppm)	Severity
Methane	0-88,000 ppm	5000	0-17
Ethane	200-188,000 ppm	3000	0.1-63
Propane	64-240,000 ppm	2100	0-114
Isobutane	35-21,664 ppm	1800	0-12
n-Butane	100-110,000 ppm	1860	0-60
Isopentane	0-14,000	1400	0-10
n-Pentane	0-100,000	1500	0-67
C1-C5 (Total)	800-640,000	-	-

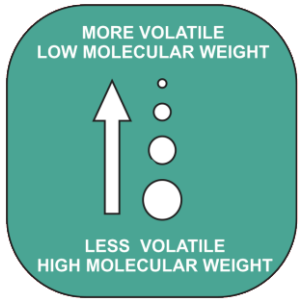
Grab Samples 0.5 meters above hatch

Analyte	Concentration Range	IDLH (ppm)	Severity
Benzene	nd-230 ppm	500	0-0.5
Ethylbenzene	nd-26 ppm	800	0-0.03
Toluene	nd-74 ppm	500	0-0.15
Xylenes	nd-190 ppm	900	0-0.2

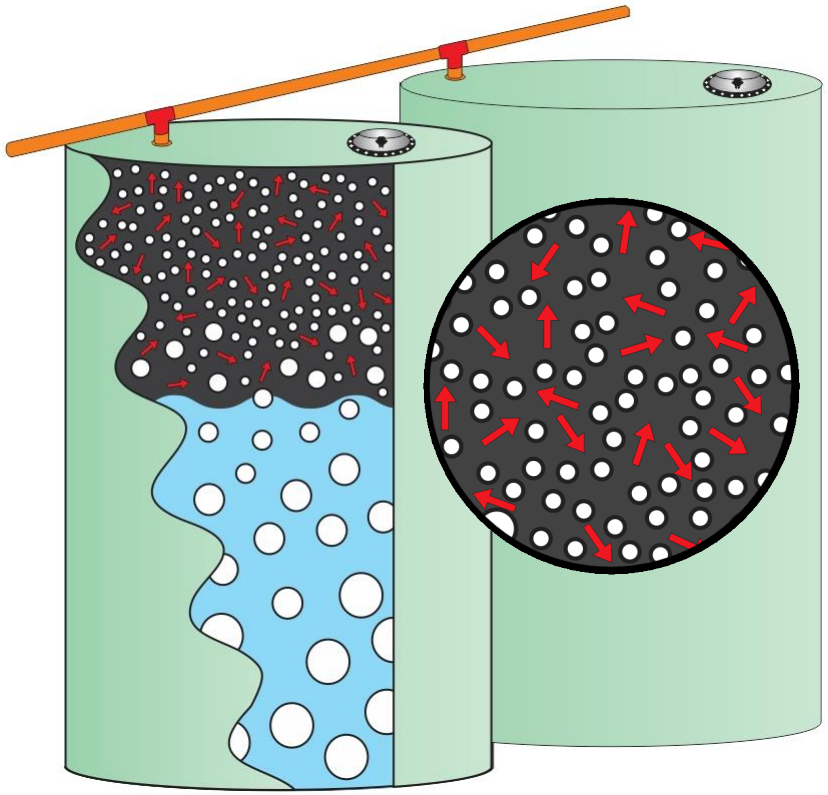
Behavior of Production Fluid Storage Vessels without NSPS 0000 Controls (pre-2012)



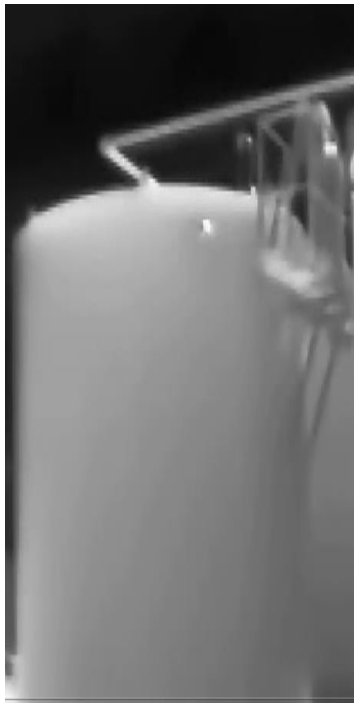
Tank is continuously vented to the atmosphere. Gases and vapors in tank are in equilibrium with outside air. No significant pressure on the tank.

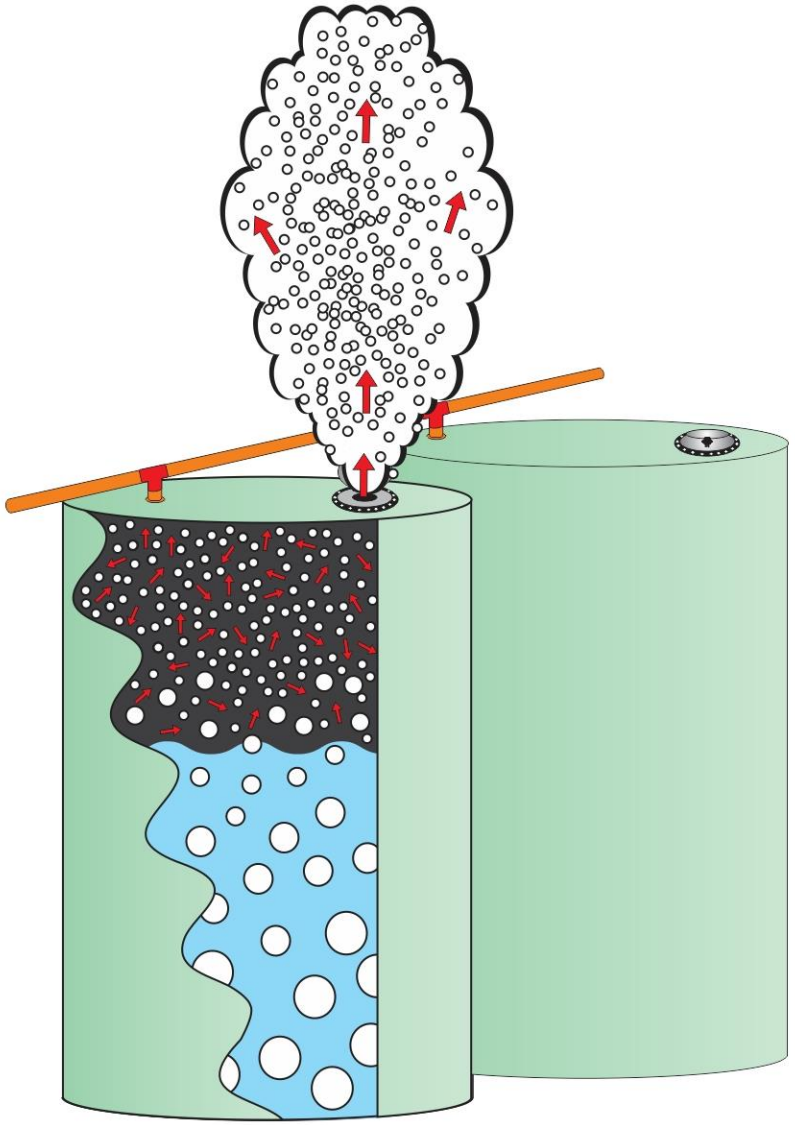


Behavior of Production Fluid Storage Vessels with NSPS 0000 Controls (post- 2012)

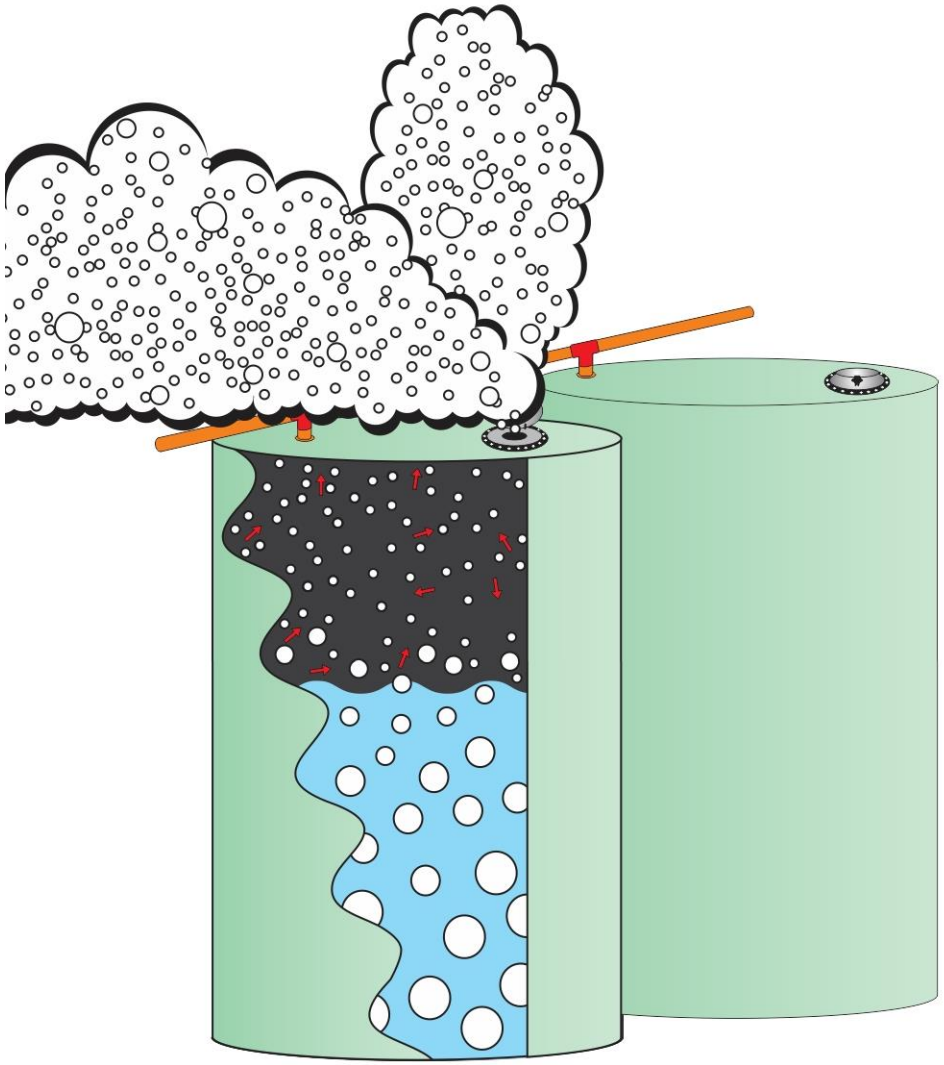


Hatch is closed. No visible emissions, greater than 95% VOCs produced are controlled. Gases and vapors in tank are in equilibrium with gas and vapors in the liquid hydrocarbon. The different gases and vapors are exerting pressure on the container.

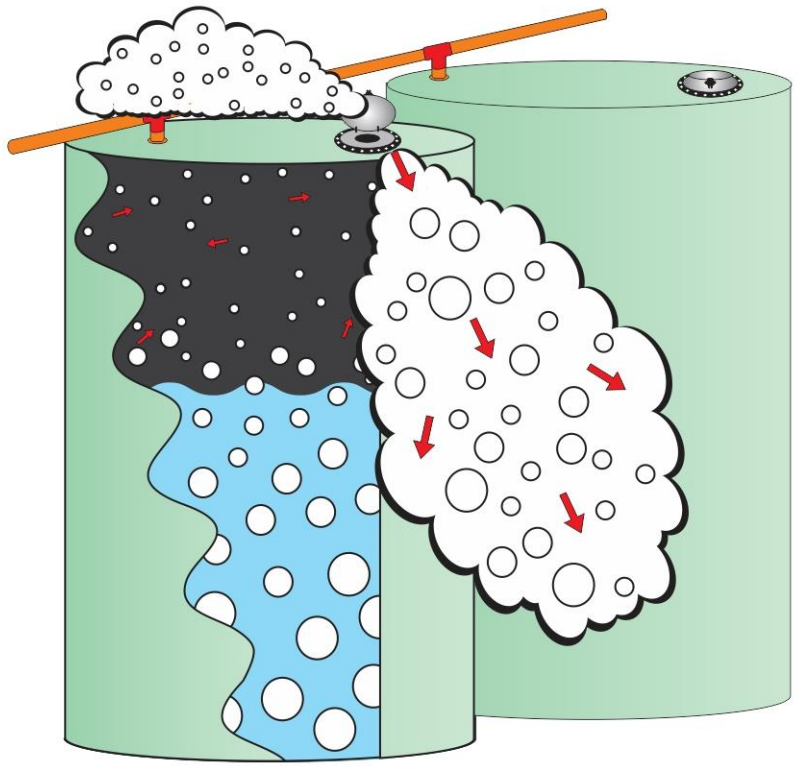




Hatch is opened. A large volume of gases (mostly propane and butane) rush out of the hatch very quickly. The “cloud” can displace oxygen in the immediate work area and presents an immediate asphyxiation hazard.



As hatch remains open, heavier hydrocarbons in the tank (pentane, hexane, heptane, BTEX) will evaporate and leave the tank and enter the workspace. Rate of flow is still high and these gases and vapors may be present at toxic and flammable concentrations.



Hatch remains open. Gases and vapors in tank are approaching equilibrium with the environment and the rate of emission slows down significantly. Heavy gas and vapors drop toward the ground.

Determinants of Released Gas and Vapors

- Production rate of the well
- Composition of fluid and inherent vapor pressure – higher vapor pressure more gas and vapors in headspace
- Pressure setting on emission controls- gas and vapor equilibrium changes with pressure,
- Number of tanks in the battery-more tanks greater volume of release
- Proper operation of vapor controls

OSHA/NIOSH/NSTEPS Alliance Hazard Alert

http://www.nationalstepsnetwork.org/docs_tank_gauging/TankHazardInfographicFinal04_22_15.pdf

Focus on Worker Exposures by Production Area

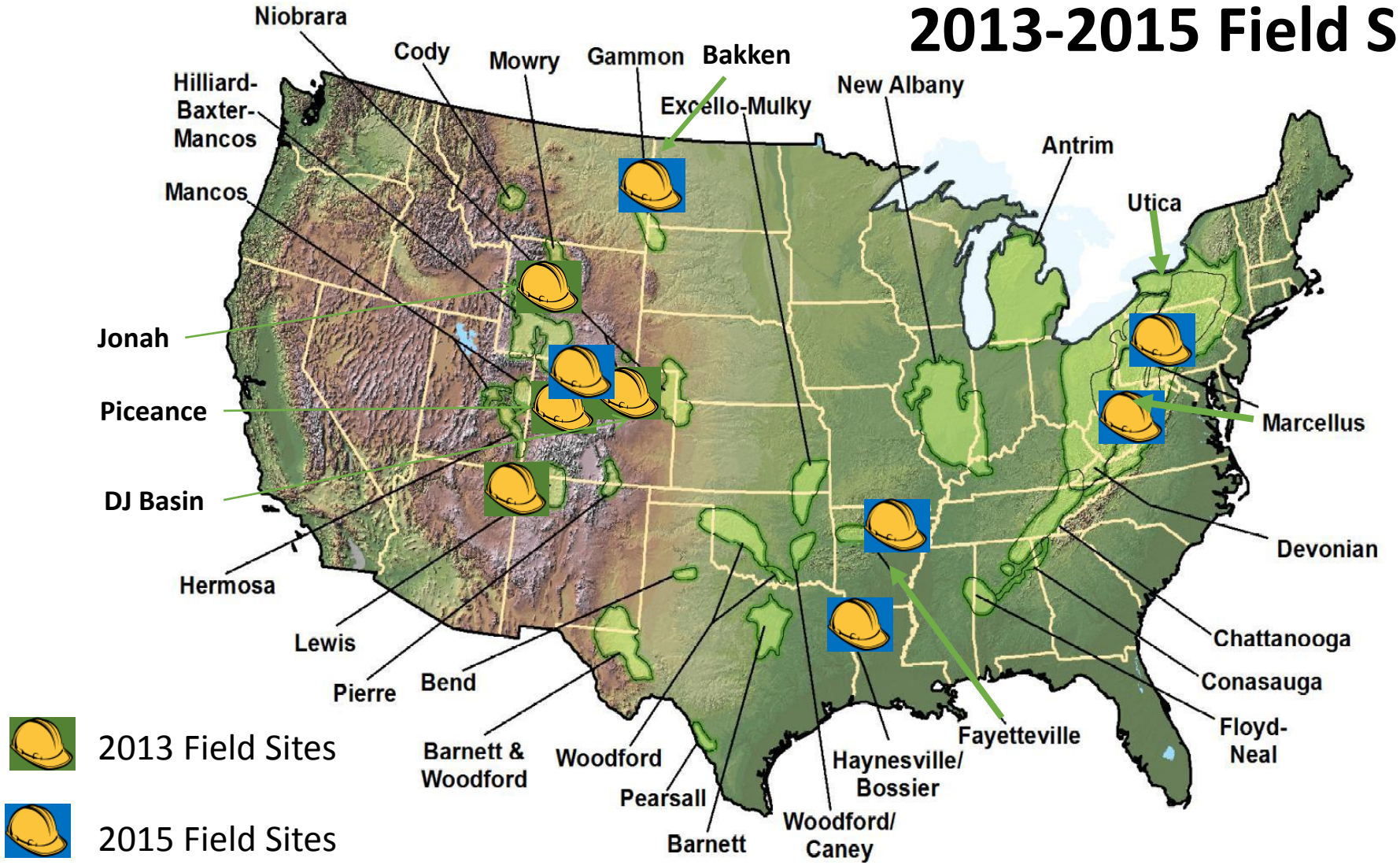
What Operations Did We Study?

- Flow Back Operation- Oil wells, Wet and Dry Gas Wells
- Lease Operators
  - Legacy wells
  - Newer Wells
- Drill Out
- Production Operators
- Pigging Operations

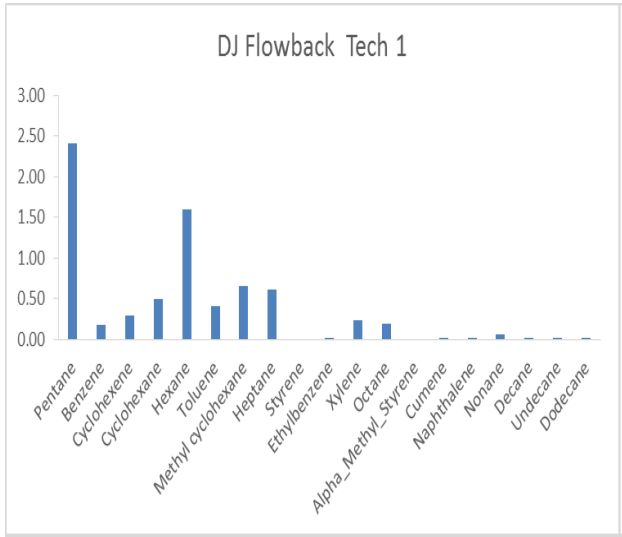
What Areas or Basins

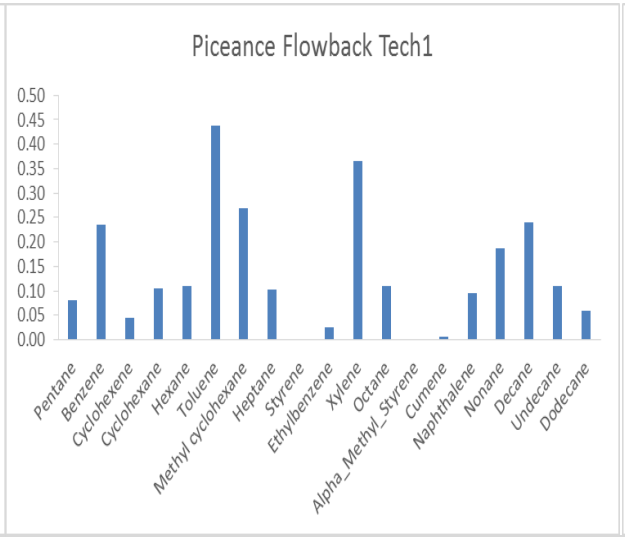
- Fayetteville Shale- Dry Gas
- Marcellus- Wet and Dry Gas
- Utica Shale-Wet Gas
- DJ- Oil and Gas
- Piceance-Oil and Gas
- San Juan-Oil and Gas
- Jonah-Oil and Gas
- Bakken-Oil

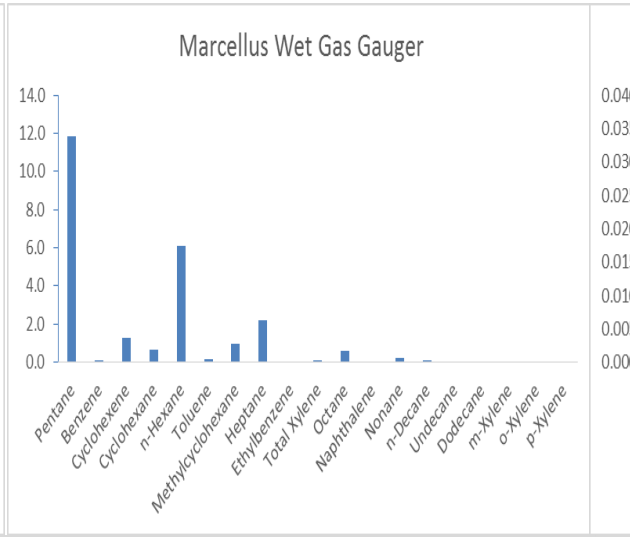
2013-2015 Field Sites

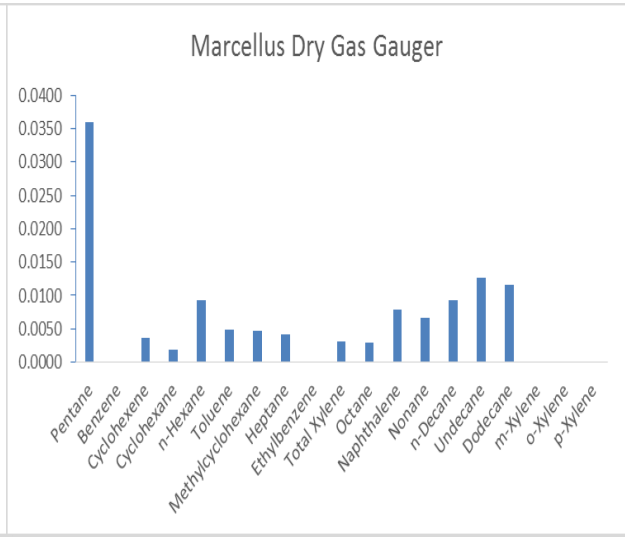


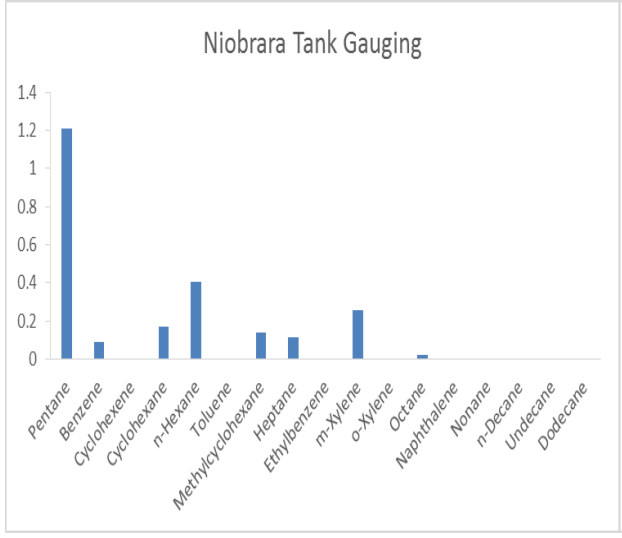
Comparison of PBZ Gas and Vapor Profile by Basin

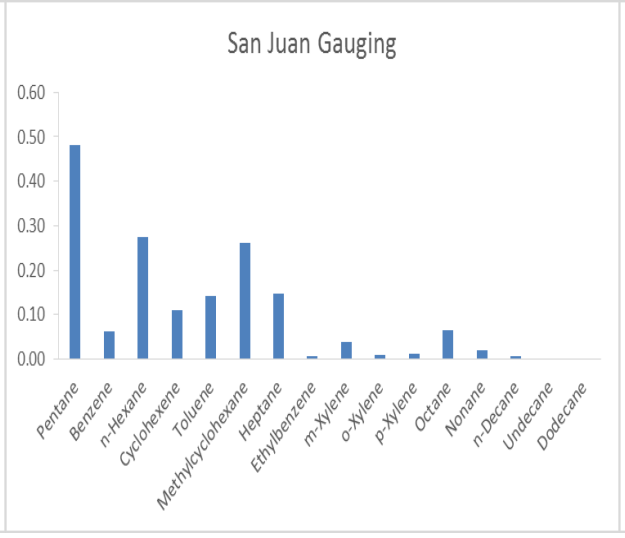


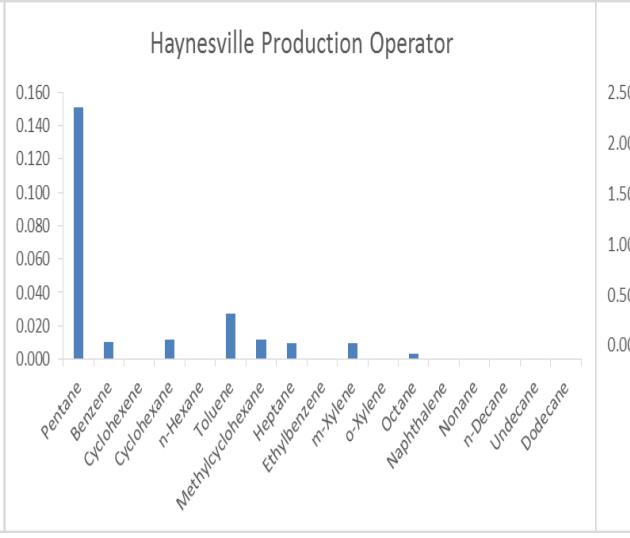


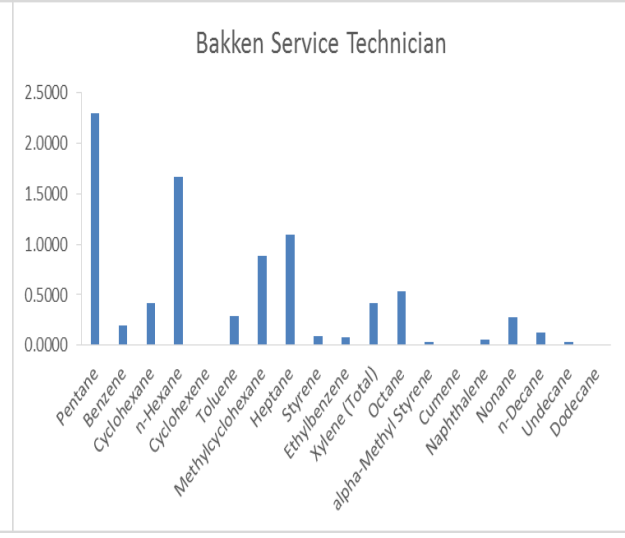




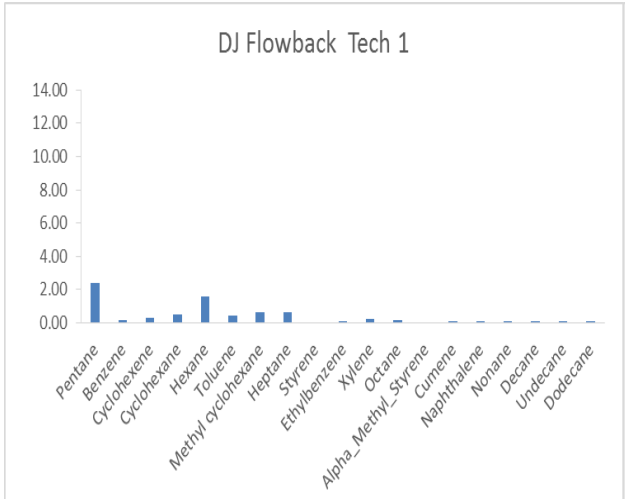


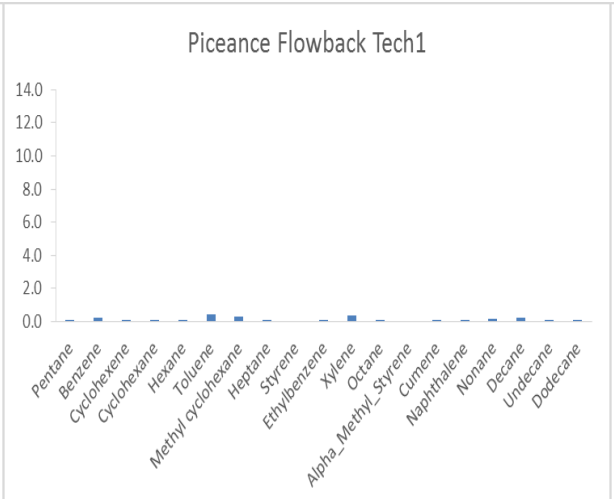


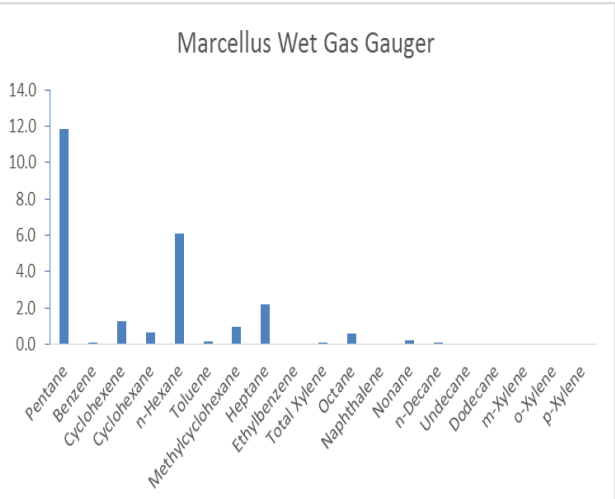


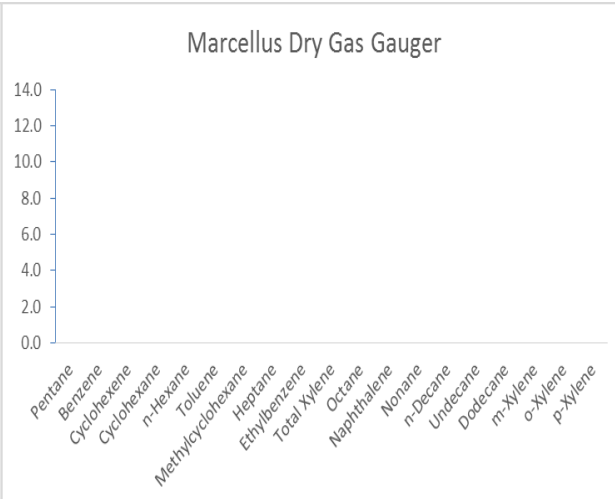


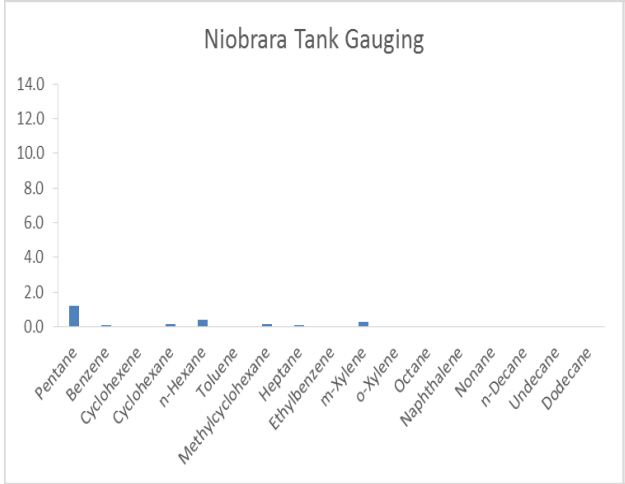
Previous Graphs on the Same Scale

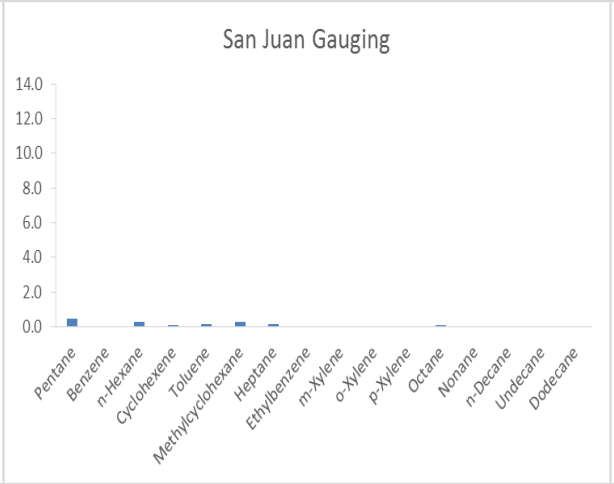


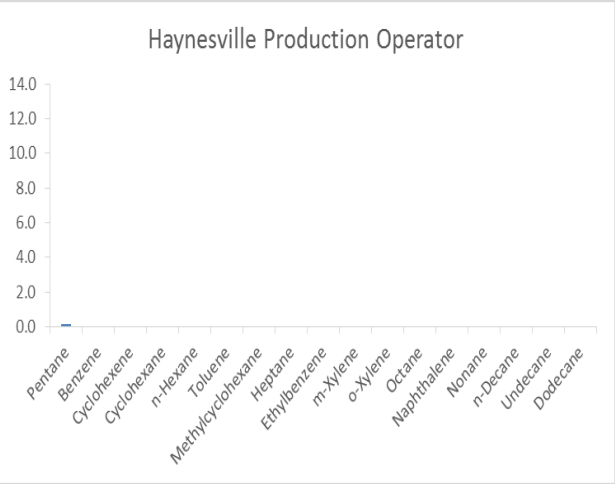


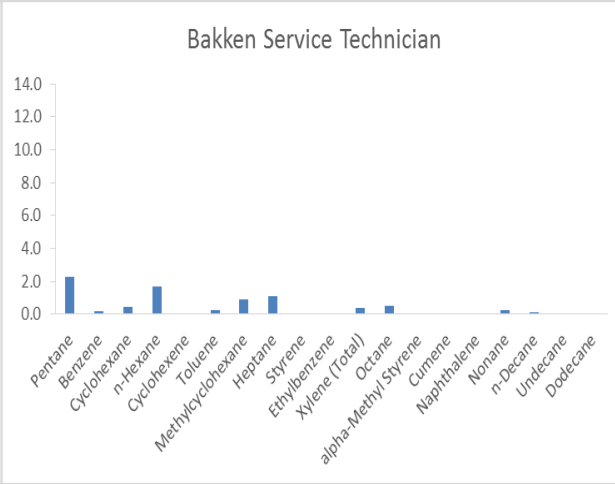




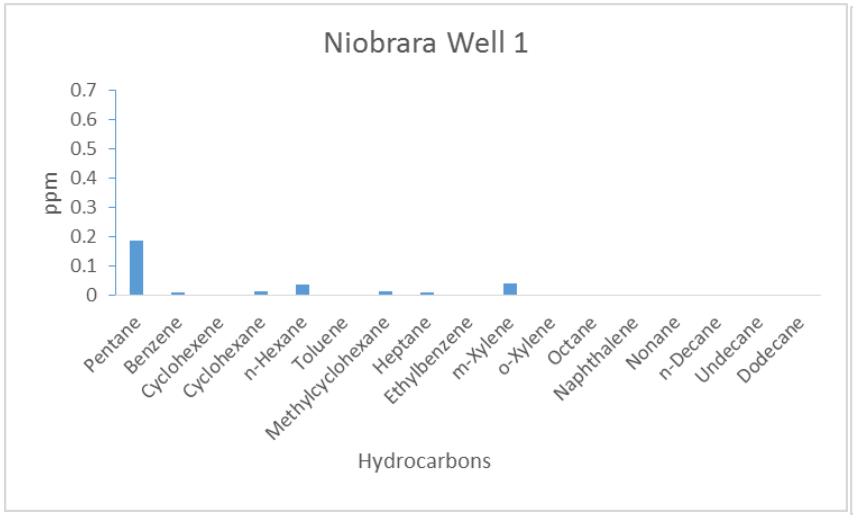


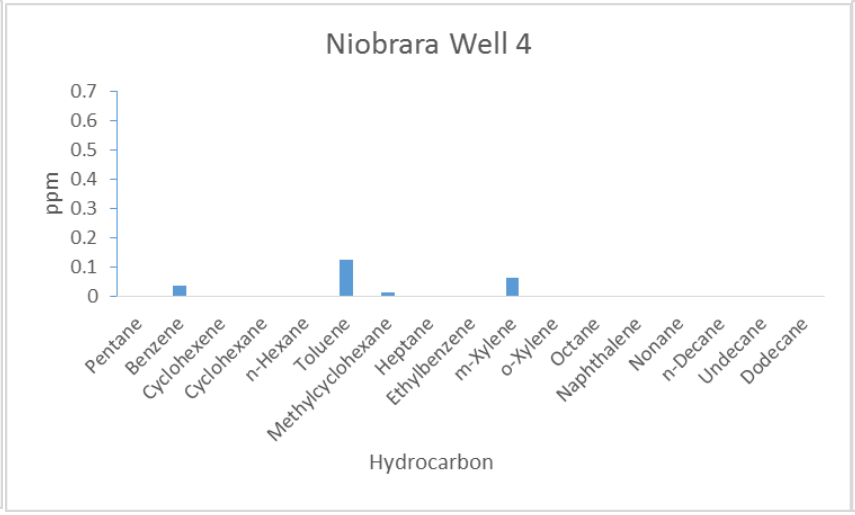


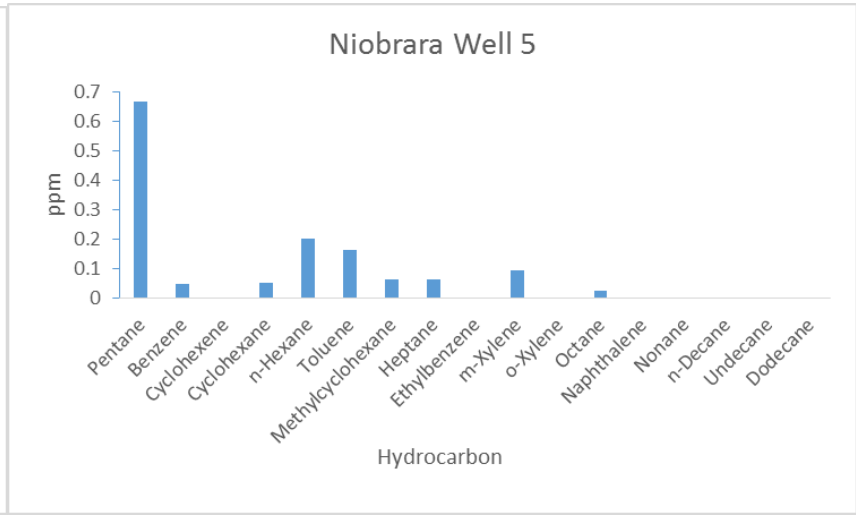




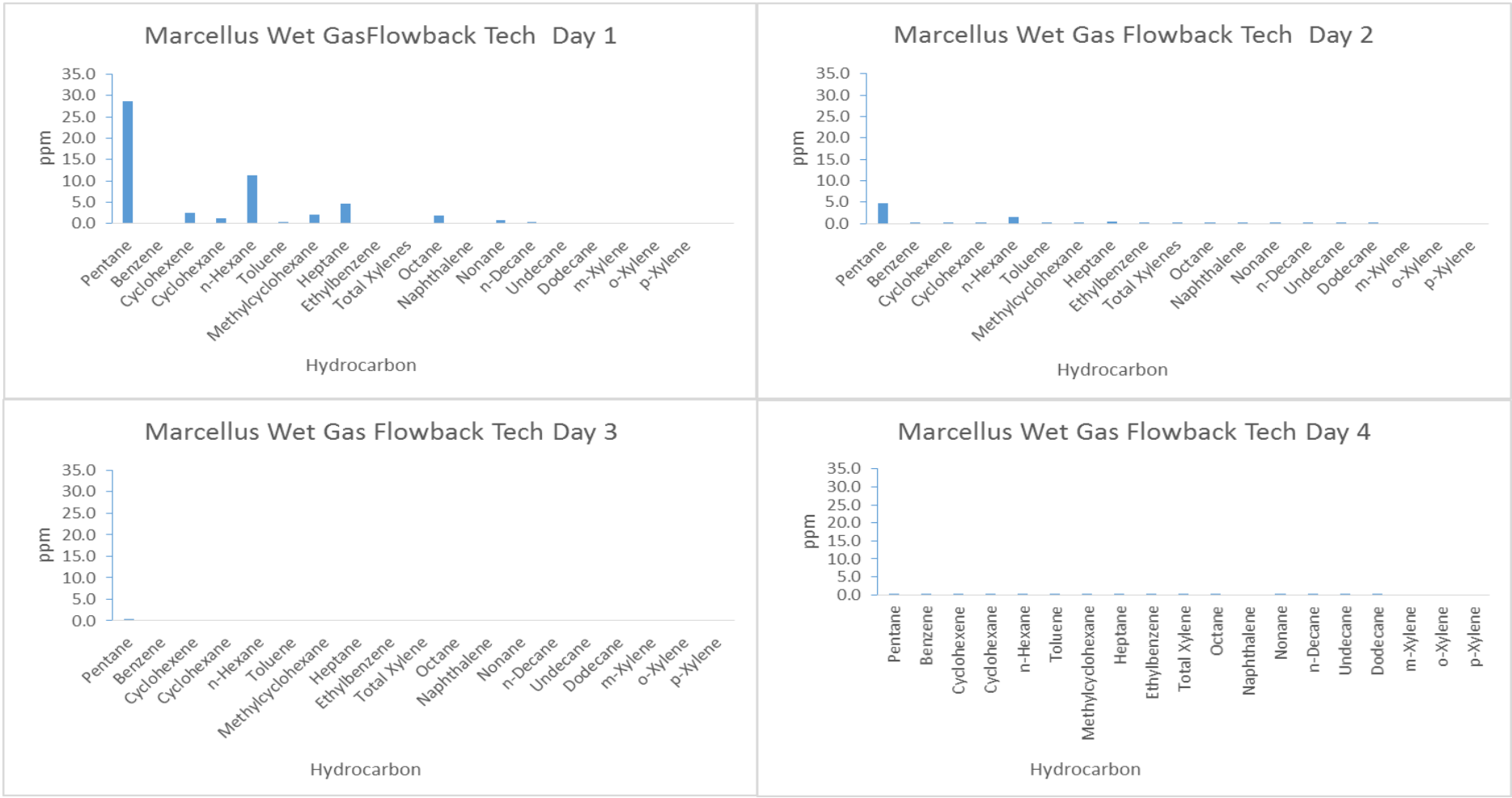
Variation in composition and concentration in PBZ samples collected in the Niobrara (CO) Basin Different Wells.







Variation composition and concentration in PBZ samples collected on a flowback worker over 4 days at the same well in the Marcellus (PA) basin.



Development and Evaluation of Controls

Photo courtesy of Eric Esswein, NIOSH

NIOSH Mini-Baghouse Retrofit

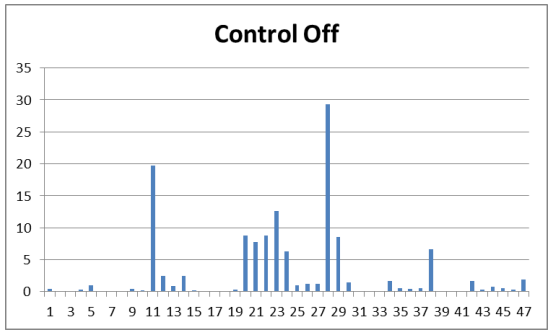
- Proof of concept, June 2012, 2nd and 3rd generation versions
- Patent pending
- Fills immediate need: engineering control for silica dust
- A “bolt on control”
- No need to remove the sand mover from the field

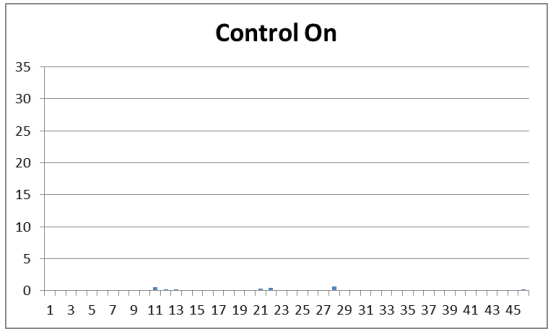
2012

2014

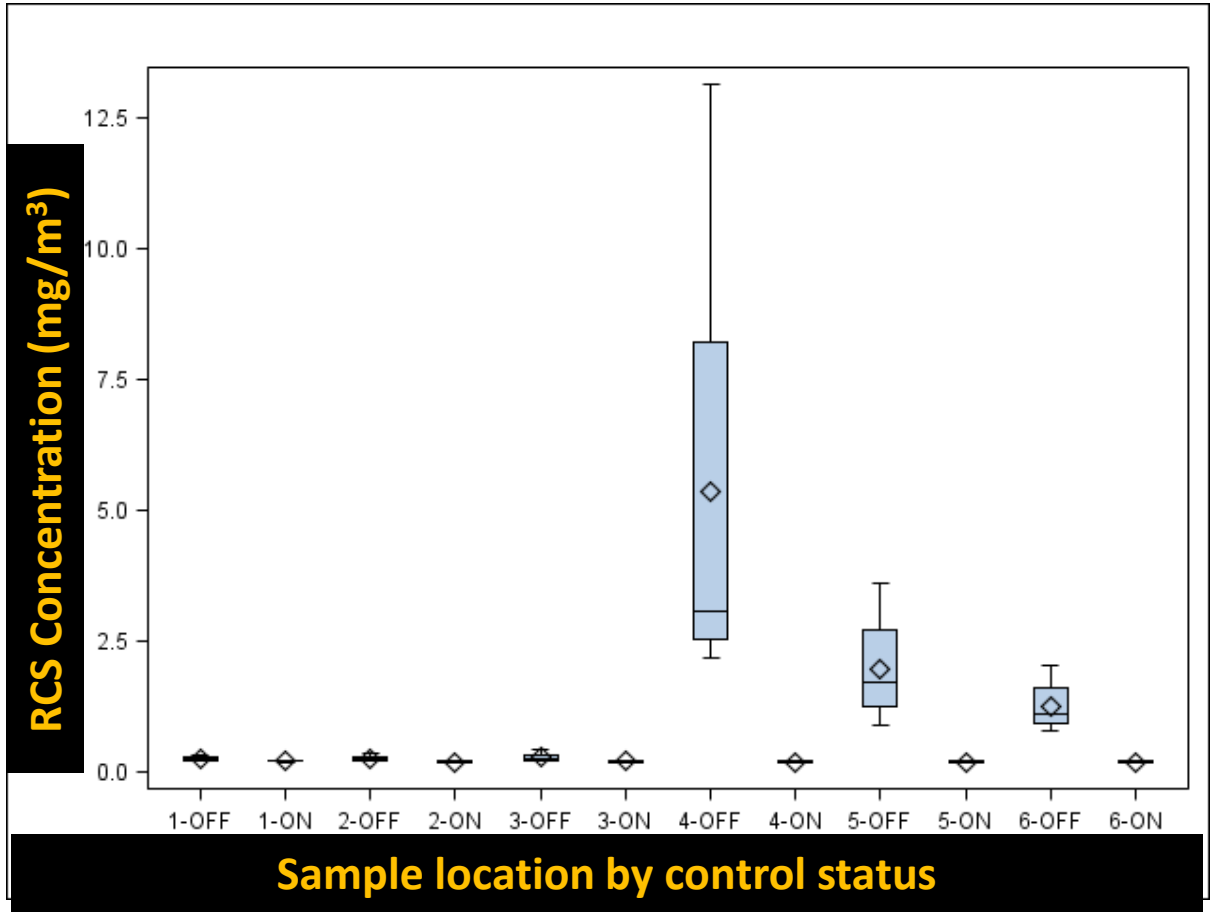
2015

Effectiveness of Mini Baghouse Retrofit Assembly





Reductions in respirable crystalline silica concentrations ranged from 79% to 99% when using the mini-baghouse



Plotted by H. Amy Feng, NIOSH

The 3rd-generation Mini-Baghouse design has improved features:

- Increased surface area of filter cloth
- Dust-release coating on the inside of the bag
- More resistant to leaks

Photos courtesy of Dylan Neu, NIOSH

Tests with the redesigned mini-baghouse are currently underway

- Eric Esswein funded by CDC I-Fund Program for expanded field evaluation
- New partners are stepping up to perform real-world evaluations
- Opportunity to evaluate multiple control strategies simultaneously

Future Directions for NIOSH Exposure Assessment Research in the Oil and Gas Extraction Industry

- Acute Exposure Hazards (VOC exposures, flammability hazards) During Handling of Crude, Produced Water, etc.
- Flowback (VOCs, aldehydes, alcohols, BTEX)
- Long term eval: NIOSH Mini Baghouse Retrofit Assembly Long term goal: licensing, adoption
- Drilling (VOCs, diesel particulate [DPM], silica)
- Servicing Operations (NORM, VOCs, DPM)

Questions?

Alice Hamilton, M.D.
Mother of U.S. Occupational Medicine
1869–1970

Email: jts5@cdc.gov

Disclaimer: The findings and conclusions in this presentation are those of the author(s) and do not necessarily represent the views of the National Institute for Occupational Safety and Health.