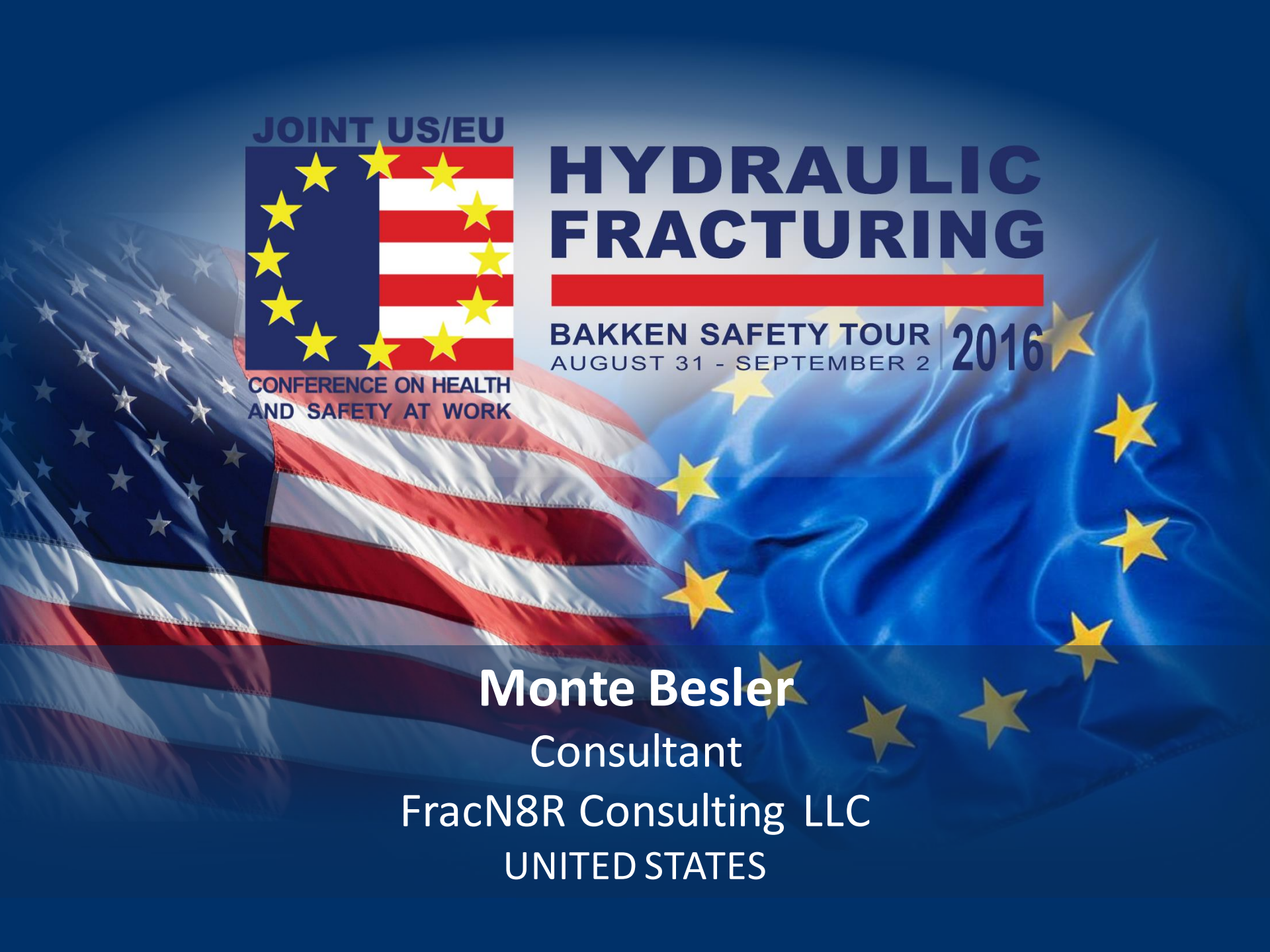


Monte Besler
Consultant
FracN8R Consulting LLC
UNITED STATES

Engineered Safety and Environmental Aspects of Well Construction and Fracturing Design

Monte Besler

FRACN8R Consulting, LLC

Surface Considerations

- Design Hydraulic Fracturing Treatment
- Determine Maximum Pressure and Injection Rate Requirements.
  - Location size equipment considerations.
    - Fluid heating units.
    - Fluid transfer pumps.
    - Fluid blending units.
    - High pressure slurry pumping equipment.
    - High pressure discharge manifold.
    - Treating line pressure relief valve and flowline.
    - Remote operated wellhead valve control station.
    - Wireline equipment staging area, if applicable.
    - Flowback manifold, sand trap, three phase separator, flare stack, and flowback tanks.

Surface Considerations

- Determine Fluid and Material Requirements.
  - Location size to accommodate fluid and material storage.
    - Water storage tanks.
      - Bulk tanks or pit storage.
      - Working tanks.
    - Proppant storage units.
    - Flowback storage tanks.
      - Oil
      - Water
  - Determine necessary spill berm volume.
    - Typically around 1.5 times fluid storage volume.
  - Determine logistics access requirements.
    - Sufficient lease road width.
    - Truck maneuvering, loading, and unloading area.

Methodology

- Determine Treatment Conductor Requirement
- Design Required Wellbore
  - Casing Size
    - Fracturing Treatment and Production Considerations.
  - Casing Grade
    - Hydrogen Sulfide present?
    - Corrosive fluids present?
  - Casing Weight
    - Determined by Pressure Rating Requirement.
  - Setting Depth

Wellbore Construction

- Surface Casing to cover deepest potable water source as per regulation.
  - Casing must be cemented to surface.
  - Perform top outside cement job, if cement not circulated to surface.
    - Prevents surface wellsite fluids from entering wellbore and contaminating groundwater.
  - Set and pressure test BOP.
  - Drill out and pressure test casing shoe to insure good seal.
  - May be set deeper than regulatory requirement for drilling considerations.

Wellbore Construction

- Intermediate Casing set to target formation.
  - Cemented as required for isolation of overlying formations.
    - Supports casing.
    - Protects casing.
  - Cement fill verified using appropriated cement evaluation logging tools.
    - Typically a Cement Bond Log and/or Ultrasonic Cement Evaluation Tool.
  - Casing inspection tool needed when used as treatment conductor.
    - Typically an internal caliper log coupled with magnetic thickness sensor.
    - Pressure rating must be certified.
  - Casing must be rated above maximum treating pressure, with regulatory stipulated safety factor applied, when used as treatment conductor.

Wellbore Construction

- Production Liner set through producing formation.
  - Cementing not required if wellbore confined to single regulatory producing interval.
  - Liner hanger packer required if production liner is not cemented.
    - Necessary to isolate upper wellbore from exposure to hydraulic fracturing pressure
    - Sometimes run as backup pressure isolation when production liner is cemented.
    - Swellable packers commonly used to provide additional pressure isolation between intermediate and production liner.

Wellbore Integrity

- Wellbore environmental safeguards.
  - First level is properly designed treatment conductor.
    - » Cemented intermediate casing, inside cemented surface casing through production liner.
      - Provides two layers of steel pipe and one or two layers of cement between fracturing or produced fluids, and potable groundwater.
    - » Tie-back liner, inside cemented intermediate casing, inside cemented surface casing through production liner.
      - Provides three layers of steel pipe and one or two layers of cement between fracturing or produced fluids, and potable groundwater.

Pressure Control

- Second level is properly rated surface wellhead and high pressure treating line.
  - Wellhead typically rated to greater than the maximum expected treatment pressure.
    - » Minimum of two manual wellhead valves.
    - » Lowest valve used as master valve.
    - » Additional one or two hydraulic remote actuated valves.
  - High pressure treating line rated to greater than maximum expected treatment pressure.
  - Number of treatment lines run to wellhead determined by maximum anticipated injection rate and size of high pressure treating line.
    - » High pressure treating line inspection and testing must be current.
    - » Pressure test high pressure treating line to maximum treating pressure regularly during treatment.

Pressure Control

- Wellbore casing over-pressure protection.
  - First level is operator supervision during fracturing treatment.
  - Second level is individual fracturing unit electronic pressure limit shutdown.
    - Shuts down individual pump indicating over-pressure.
    - Unit shutdown settings commonly staggered from above expected working pressure to near maximum pressure limit.
  - Third level is global fracturing unit electronic pressure limit shutdown.
    - Shuts down all pumps when pressure setting value is exceeded.
    - Typically set below maximum pressure limit and above highest individual pump shutdown setting.
  - Fourth level is high pressure treating iron relief valve.
    - Opens pressure relief valve or rupture disk located on high pressure surface treating line, and vents fluid stream to surface tank.
    - Typically a single use item, but some relief valves are resettable, if actuated while pumping proppant free fluid.
    - Must have functional check valves in the surface high pressure treating line, between the pressure relief valve and the wellhead, to prevent uncontrolled well flowback.
    - Remote actuated wellhead typically shut if immediate resumption of pumping is not possible.

Pressure Control

- Additional wellbore pressure control measures.
  - Pressure relief valve on annulus between intermediated casing and tie-back liner.
    - Set at or below the maximum allowable pressure limit for the annulus determined by applying safety factor to lowest pressure rated component.
    - Flowline routed to surface tank to contain fluid if pressure relief valve actuated.
  - Valve between surface and intermediate casing opened.
    - Flowline routed to surface tank to contain fluid, if intermediate casing fails and surface casing exposed to wellbore pressure.
    - Prevents over-pressure failure of surface casing wellhead flange and possible loss of wellhead.

Fluid Safety

- Common household materials utilized whenever possible and practical.
  - Acetic acid – vinegar
  - Potassium Chloride – muriate of Potash – fertilizer
  - Guar gum – food thickener
  - Sodium hydroxide – lye - oven and drain cleaner
  - Sodium chloride – table salt
  - Mineral oil - baby oil – cosmetic remover
  - Sodium borate - borax – laundry cleaning aid
  - Boric acid – antiseptic – insecticide – flame retardant
  - Ammonium hydroxide – ammonia cleaner
  - Sodium bicarbonate – baking soda
  - Sodium hypochlorite – laundry bleach
  - Hydrochloric acid – Muriatic acid – pool additive – stomach acid
  - Silicon dioxide – silica sand – very clean sandbox sand – sand proppant
  - Aluminum oxide – corundum – grinding wheels – ruby – sapphire – ceramic proppant
  - Isopropyl alcohol – rubbing alcohol – gas tank anti-freeze
  - Citric acid – citrus fruit acid – beverage acidifier
  - Limonene – citrus fruit rind extract– solvent – cleaning aid – fragrance
  - Ethyl alcohol – beer - wine – whisker - vodka

Fluid Safety

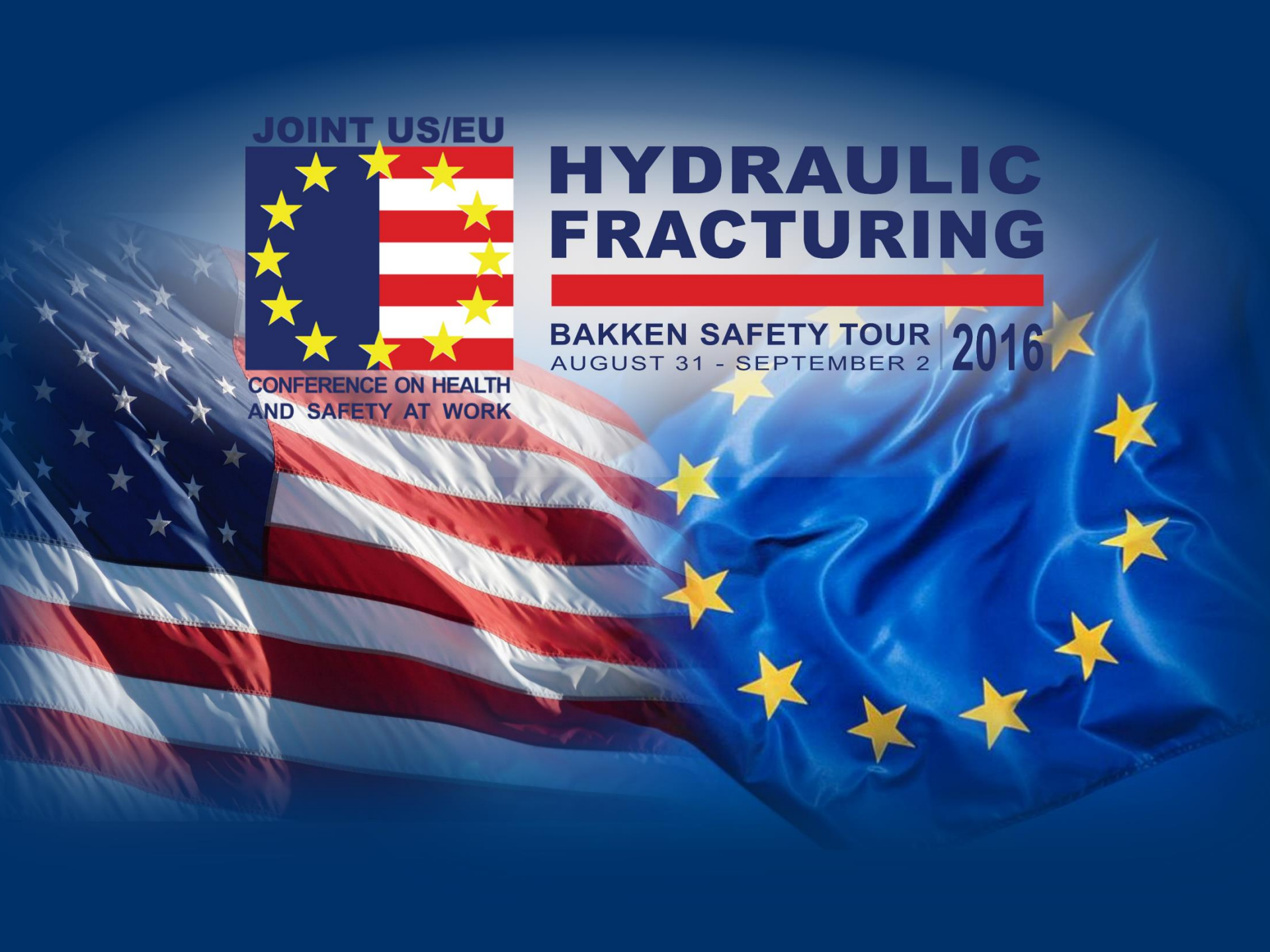
- Lots of Dihydrogen Monoxide.
- Or……

Fluid Safety

- H2O – Water

The End

- Questions?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