Oil and Gas Well Completions

Completion
Design and Engineering

Multiphase Fluid Flow

Principal multiphase flow regimes recognised in oil and gas wells:

- Bubble flow
- Slug flow
- Transition or churn flow
- Annular or mist flow

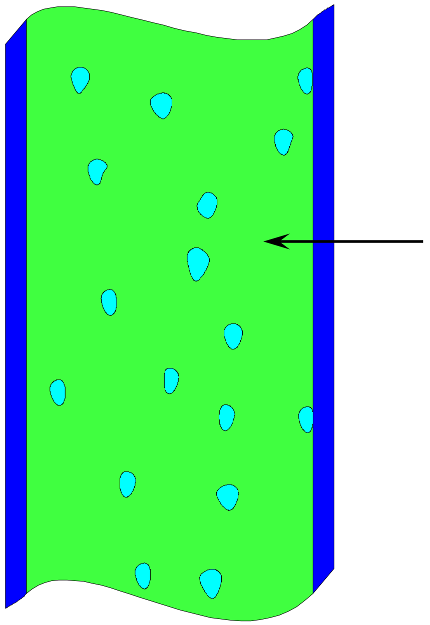
Bubble Flow

Bubble flow characterized by:

- Small evenly distributed gas bubbles
- Continuous liquid phase

Further categorized as:

- Bubbly flow
- Dispersed bubble flow

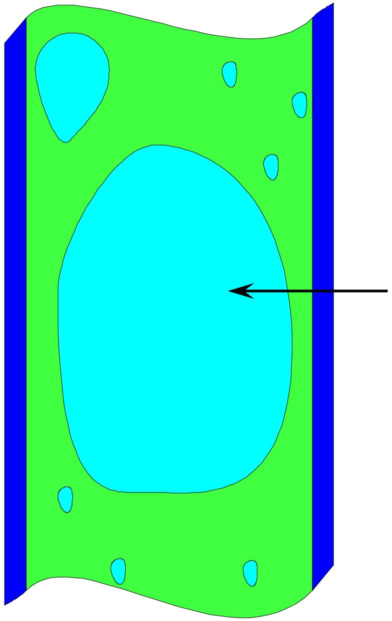


Small gas bubbles evenly distributed throughout liquid phase

Slug Flow

Slug flow characterized by:

- Series of gas pockets between slugs of liquid
- Continuous liquid phase
- Taylor bubbles

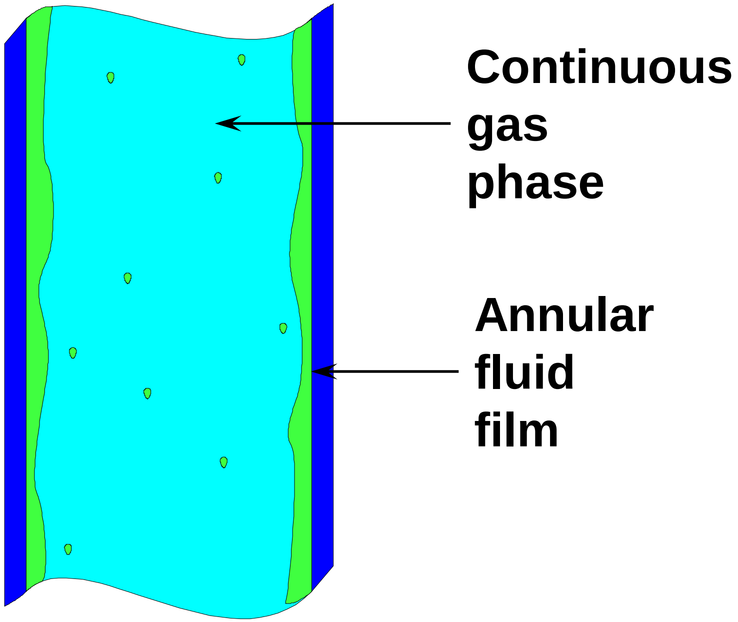


Bubbles of varying size unevenly distributed throughout liquid phase

Annular/Mist

Annular/mist flow characterized by:

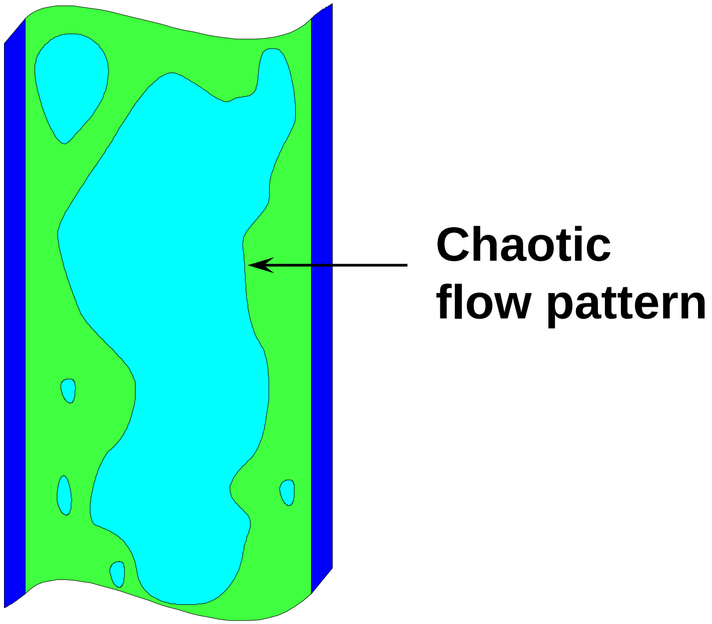
- Continuous gas phase
- Entrained liquid in gas flow (mist)
- Annular liquid film



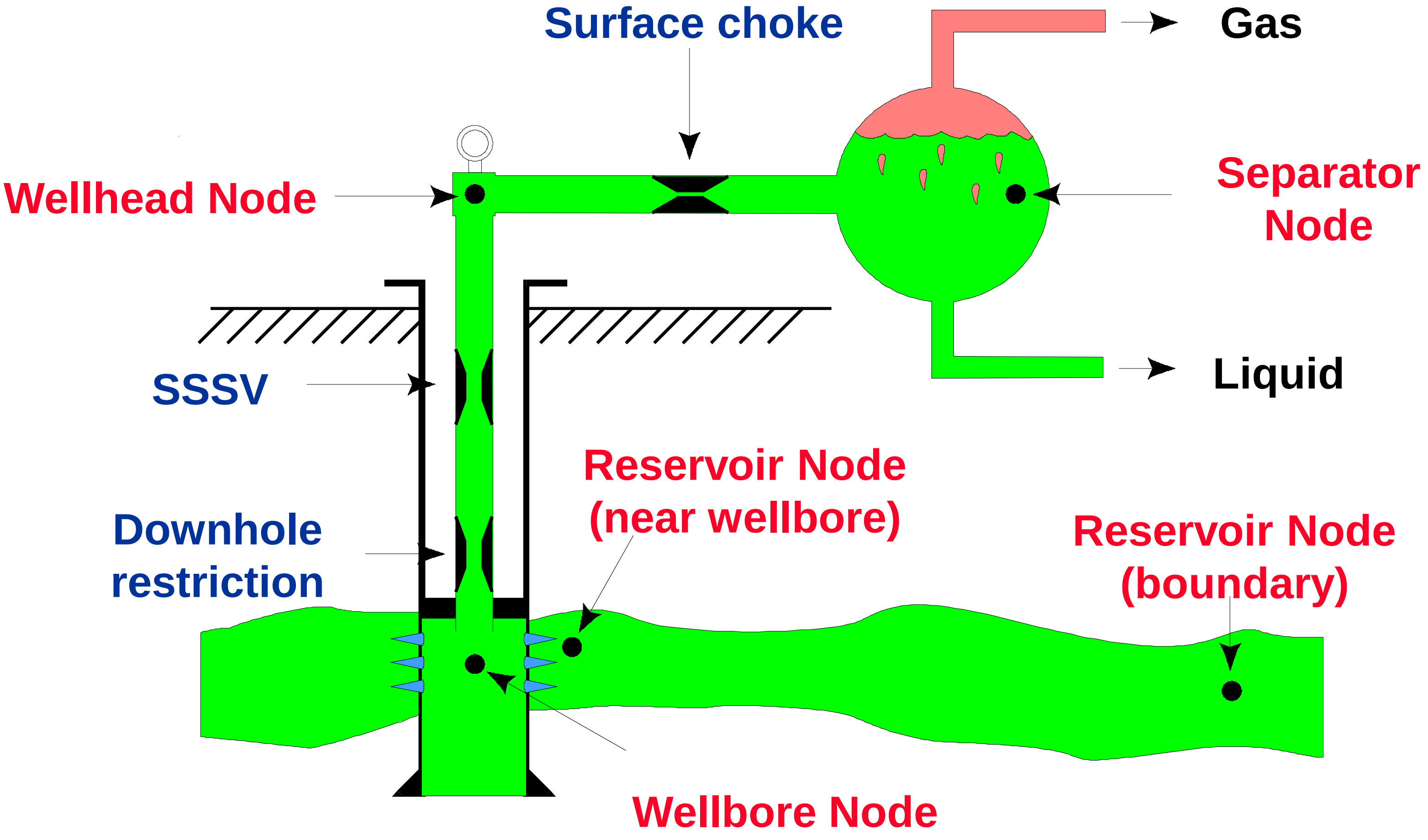
Transition/Churn Flow

Transition flow characterized by:

- Chaotic flow pattern
- Neither phase is continuous
- Liquid appears to move both up and down the conduit



Evaluating Pressure Losses

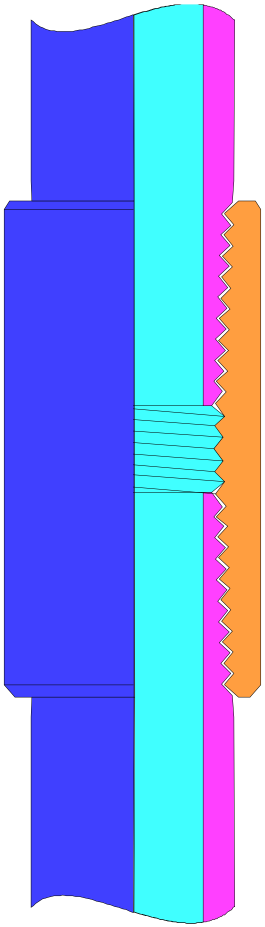


Tubing String Specification

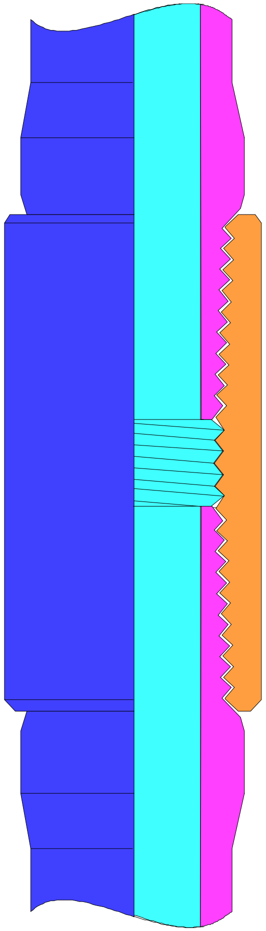
Tubing strings specified by the following:

- Size and dimensions
  - OD
  - Weight and wall thickness
  - Coupling OD
- Material grade
  - Minimum yield strength
- Construction
  - Seamless/electric welded pipe
- Tool joint
  - Nonupset/Upset
  - Premium thread

Tubing Connections - Collar

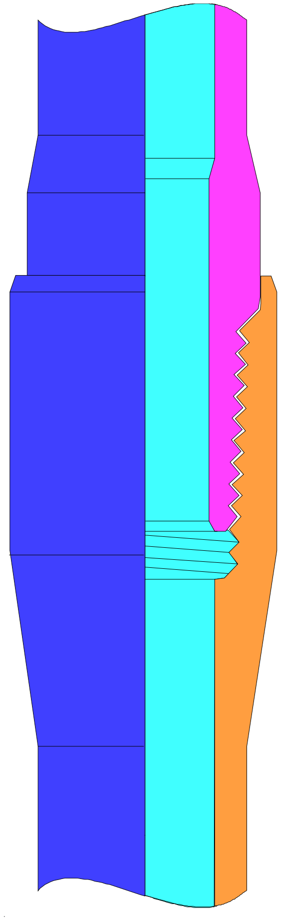


Non-upset (8 round) Connection

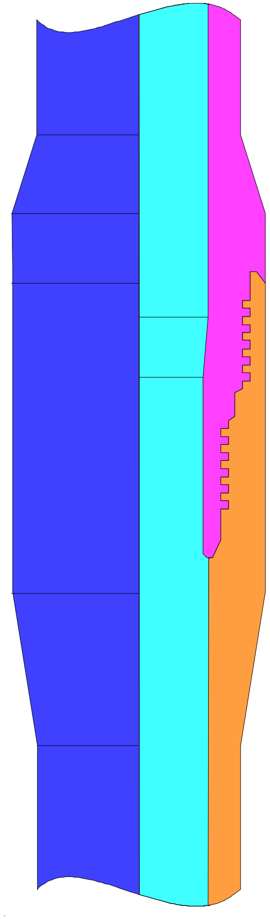


External Upset Connection

Tubing Connections - Integral



EUE
Integral Connection



Hydril
Integral Connection

String Design Factors

Criteria for string selection/design include:

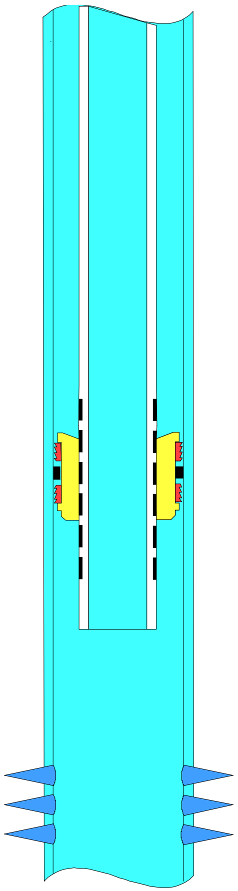
- Pressure and tension
  - < 80% of tubing yield strength
  - burst and collapse pressure limitations
- Production rate
  - flowrate should be compatible with flow area
- Wellbore environment
  - fluid properties, e.g., corrosion, wellbore deposits
- Tubular connections and geometry
  - e.g., tool joints and annular clearance
- Force and stress
  - throughout the life of the completion

Tubing Forces

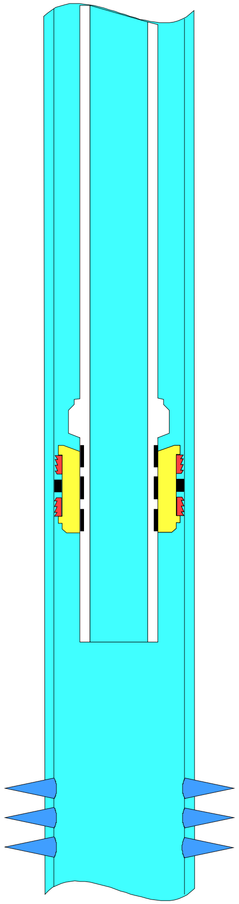
Forces and stresses on the completion can be effected by:

- Temperature
  - temperature changes
- Pressure
  - pressure changes
- Weight of components
- Fluid density and gradients
- Friction
  - especially in deviated wellbores

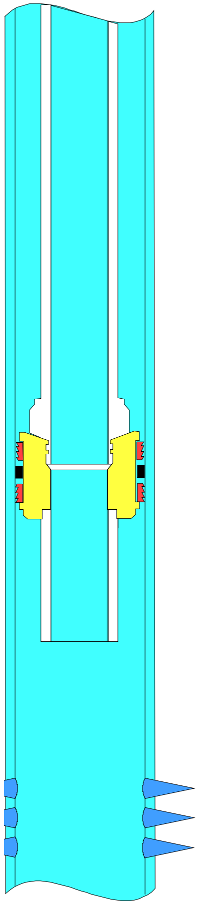
Tubing Movement- Packers



Free motion

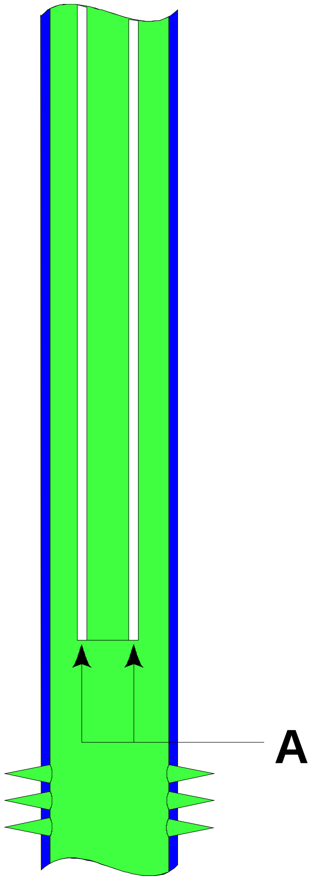


Limited motion

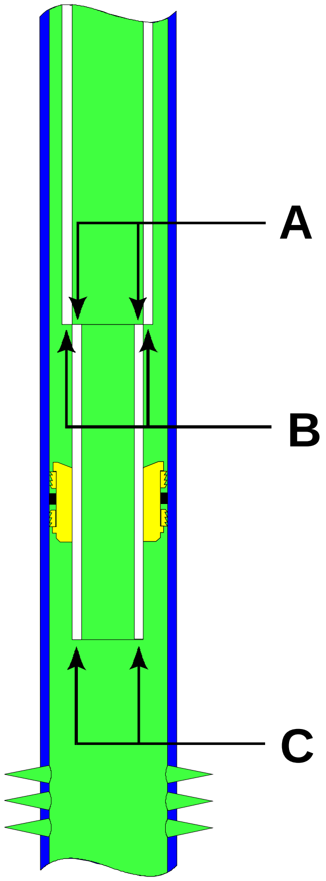


No motion

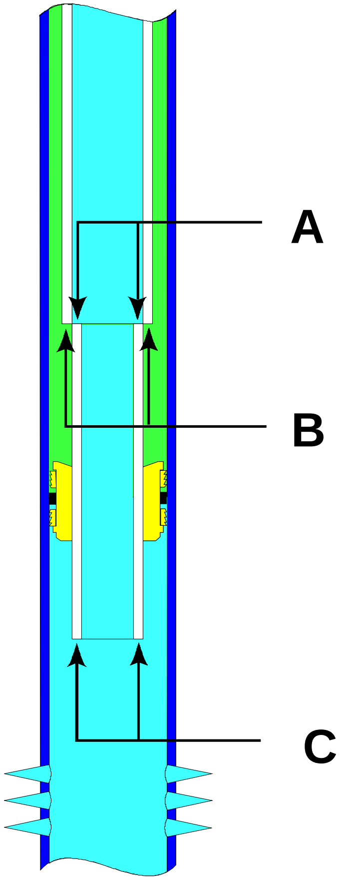
Buoyancy



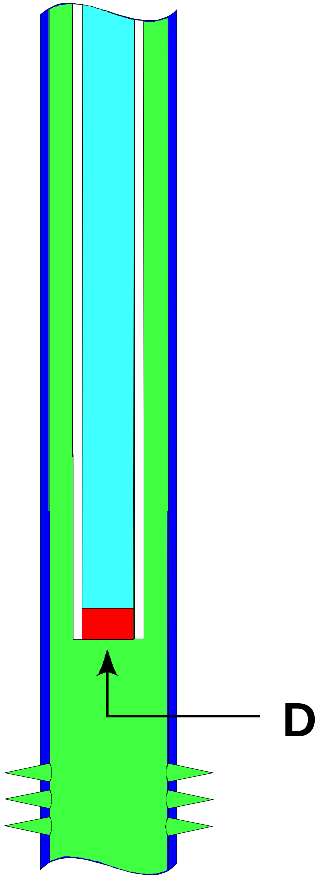
1
Open tubing



2
Tapered string



3
Tapered string



4
Plugged string

Length and Force Changes

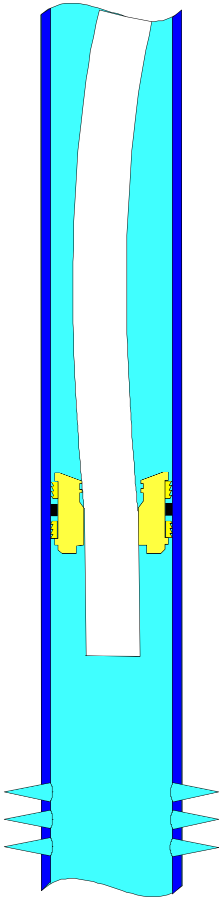
Length and forces changes should be assessed to enable:

- Selection of an appropriate packer
- Assessment of potential tubing damage
- Accurate space out and landing of the completion

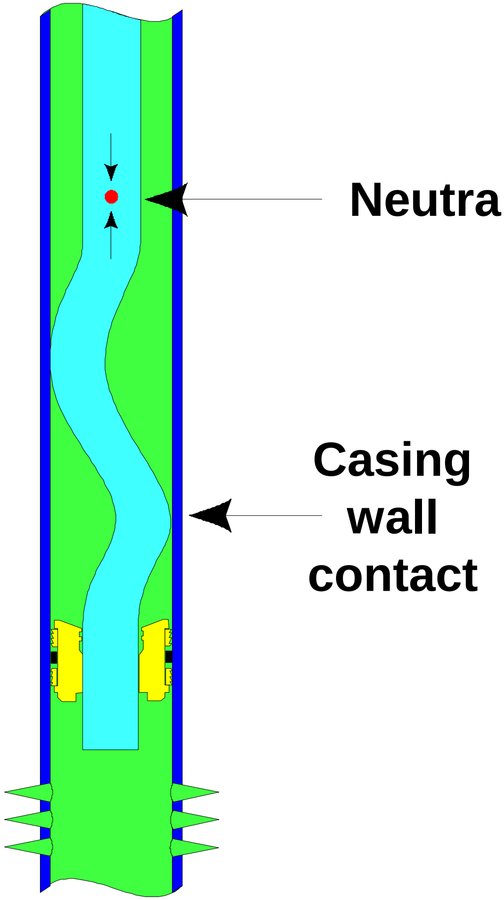
Four principal causes of length and force changes:

- Piston effect
- Buckling effect
- Ballooning effect
- Temperature effect

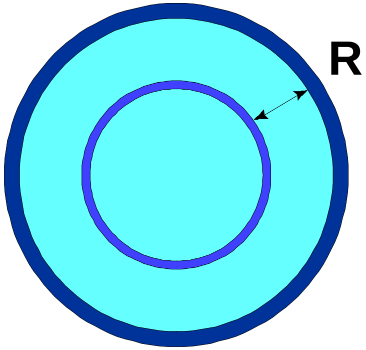
Buckling Effect



Bowed tubing



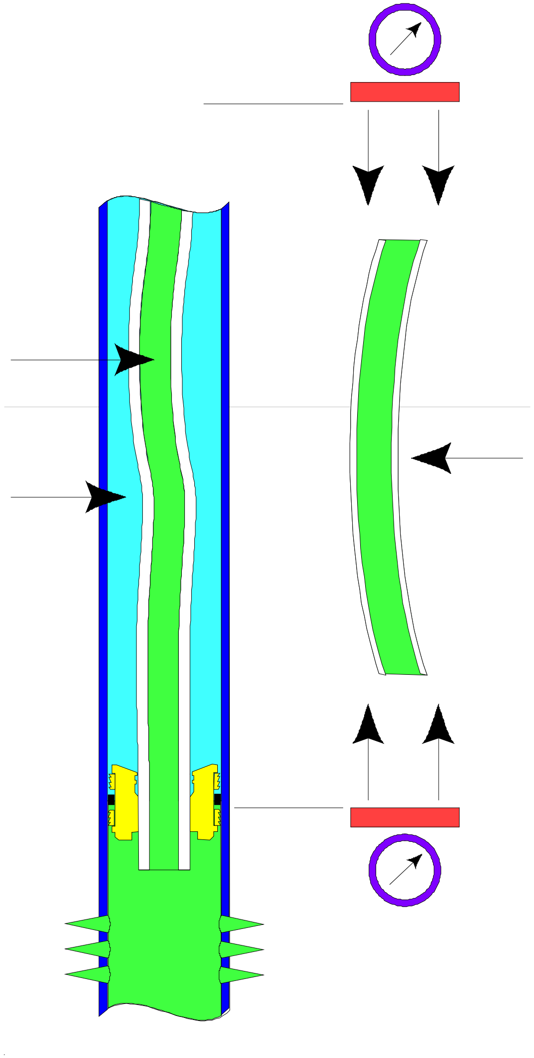
Compression buckling



$$R = \frac{\text{Casing ID - Tubing OD}}{2}$$

Radial clearance

Pressure Buckling

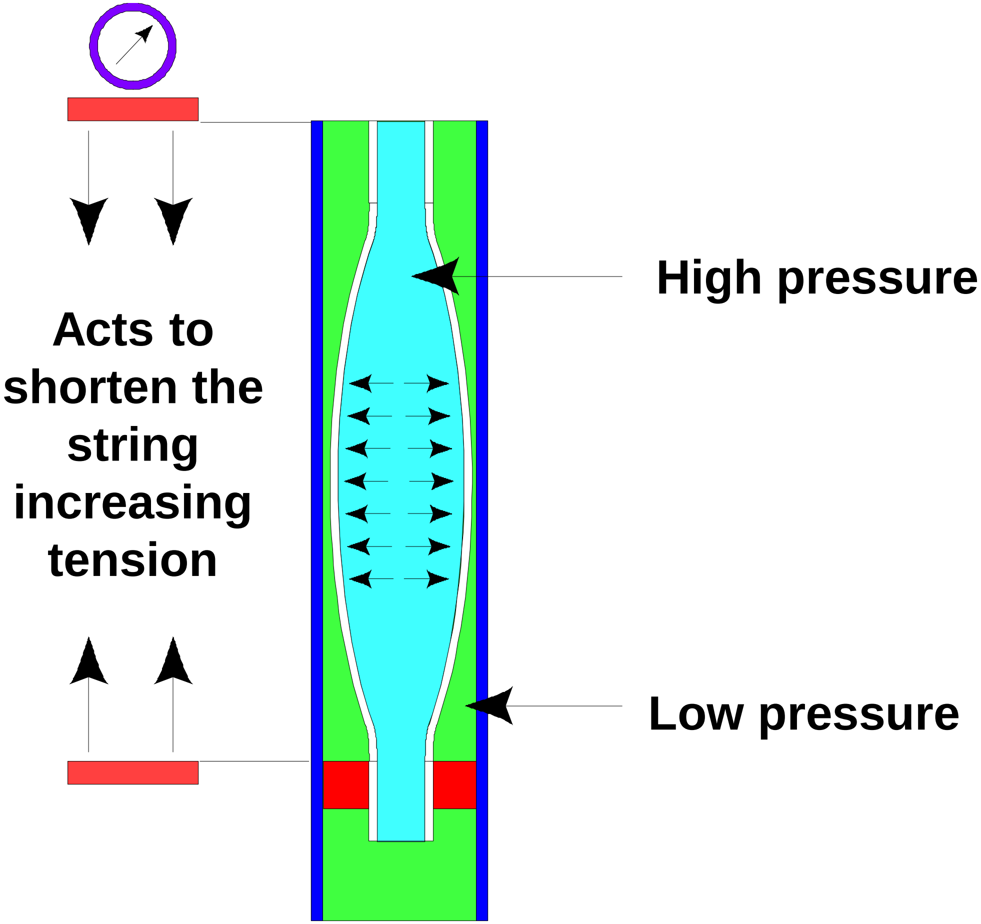


High pressure

Low pressure

Tubing
deflection
acts to increase
tension

Ballooning Effect

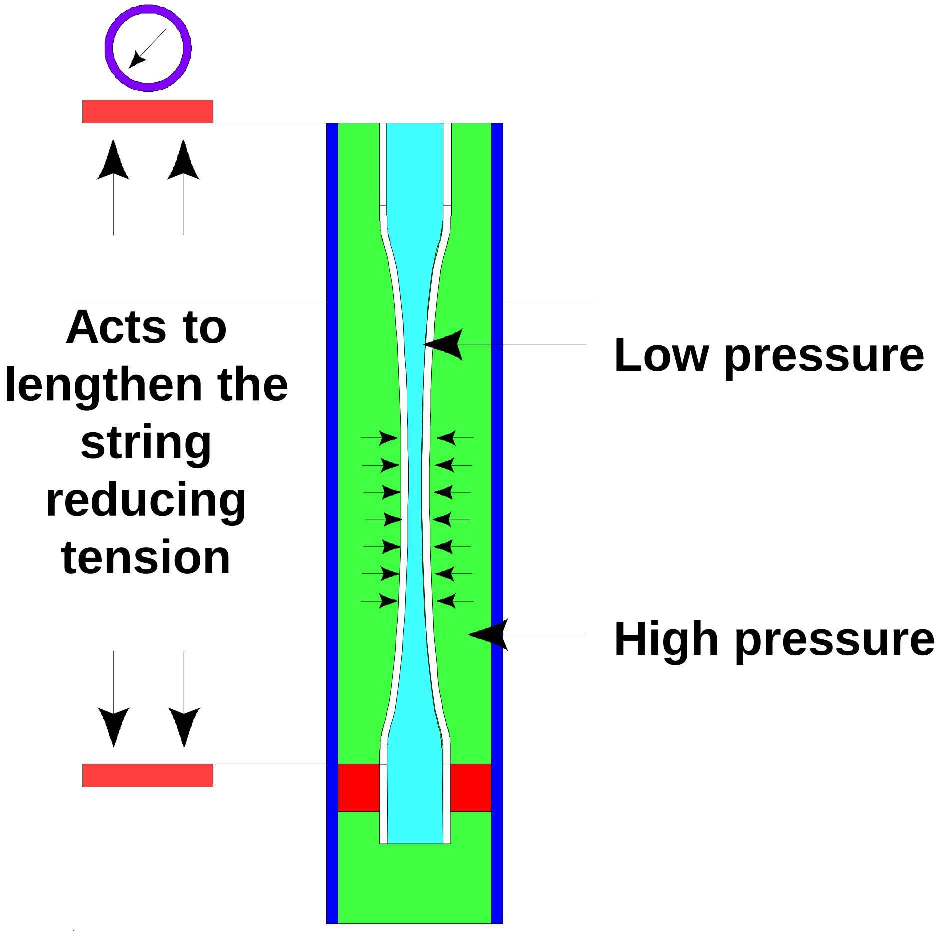


Acts to shorten the string increasing tension

High pressure

Low pressure

Reverse Ballooning

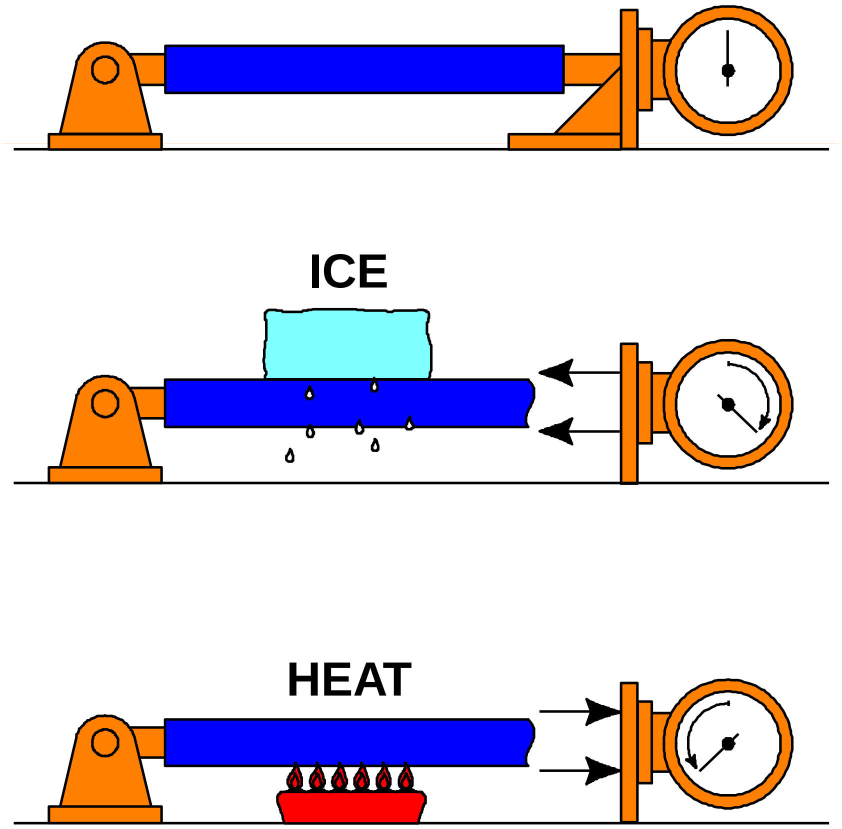


Acts to lengthen the string reducing tension

Low pressure

High pressure

Temperature Effect

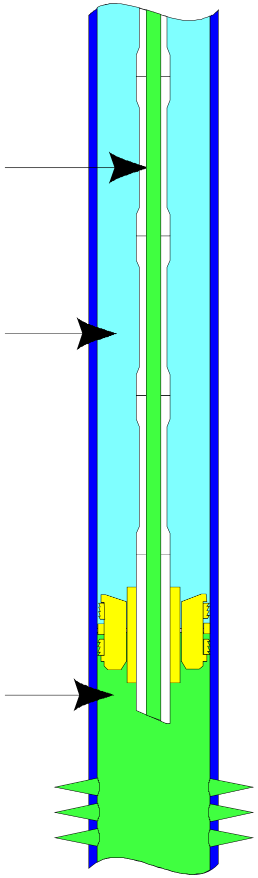


Neutral (As installed)

Cooling increases tension

Heating reduces tension

Tubing Stress Calculations

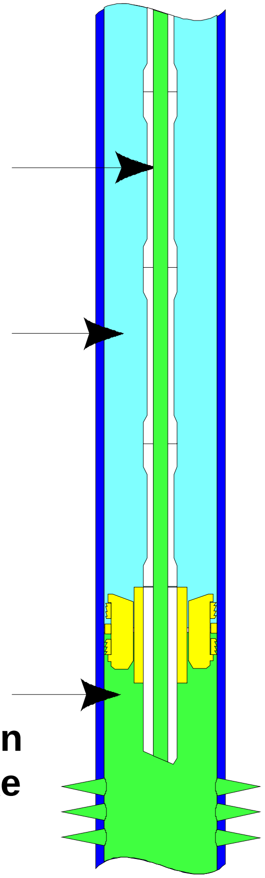


Completion fluid

Completion fluid

Mid stroke setting

1
Installation

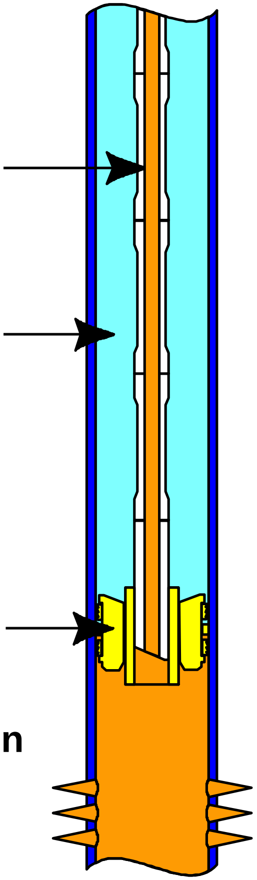


Produced fluid

Completion fluid

Seal assembly on down-stroke

2
Production



Treatment fluid

Completion fluid

Seal assembly on up-stroke

3
Treatment

Material Selection

Factors influencing material selection criteria typically include:

- Mechanical properties
  - e.g., material strength
- Operating environment
  - e.g., sour or corrosive service
- Ease of manufacture
- Cost
- Availability
  - e.g., in required dimensions

Corrosion

Failure mechanisms associated with corrosion:

- Stress corrosion cracking
  - Hydrogen embrittlement, stress cracking
- Material weight loss
  - CO_2 corrosion, oxidization, treatment fluids
- Pitting or localised loss

Requires three conditions

- Corrosive media, e.g., oxygen
- Electrolyte, e.g., moisture
- Heat or pressure

Elastomers and Plastics

General definition:

An elastomer can be stretched to at least twice its original length and will quickly return to approximately its original length on release. Plastics cannot withstand such strain without permanent damage.

Primary applications:

- Sealing components for:
  - pressure
  - fluids (liquids and gas)
  - heat

Elastomer and Plastic Limitations

Elastomers and plastics should be selected on compatibility with:

- Corrosive fluids or environment
  - e.g., reservoir or completion fluids
- Chemical compatibility
  - e.g., stimulation fluids
- Operating temperature
  - including range and fluctuation
- Operating pressure
  - including range and fluctuation
- Dimension
  - e.g., ability to function with extrusion gap

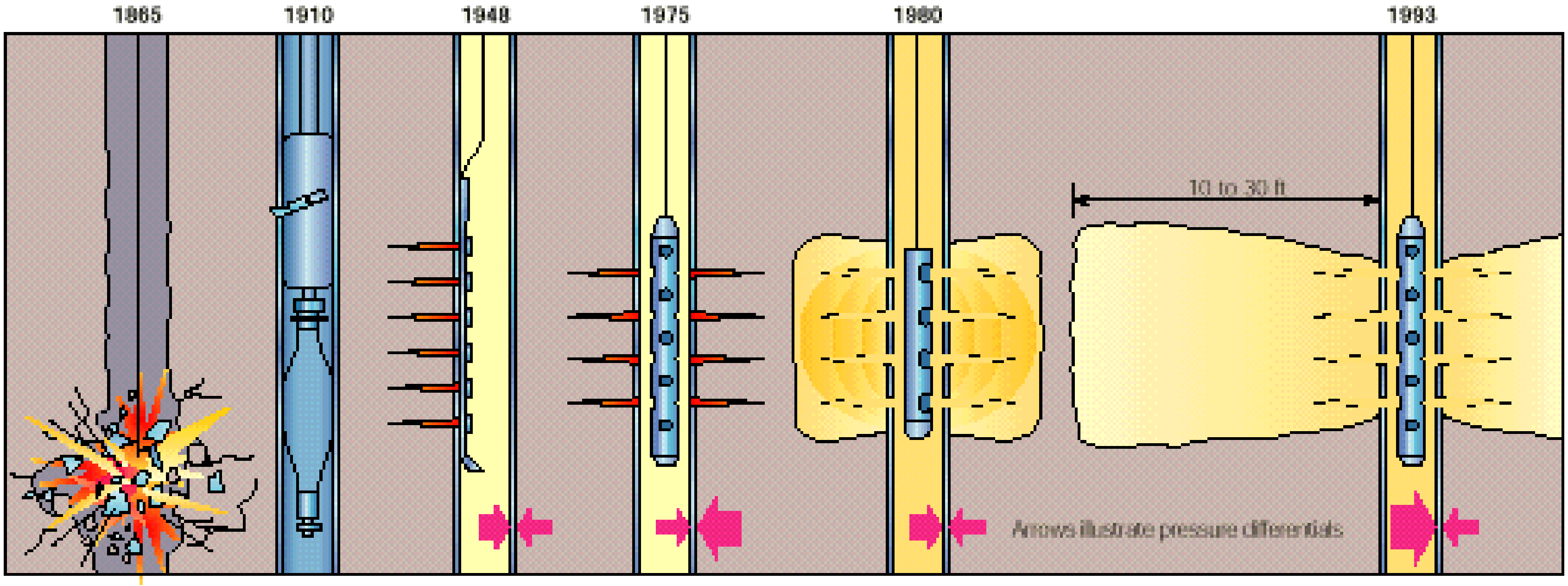
Perforating

The process of creating a clear channel of communication between the reservoir and wellbore.

Technique selection depends on:

- Completion type and dimensions
- Reservoir conditions, e.g., stability/consolidation
- Local experience and preference

Perforation History



Perforation Program Design

Principal design considerations include:

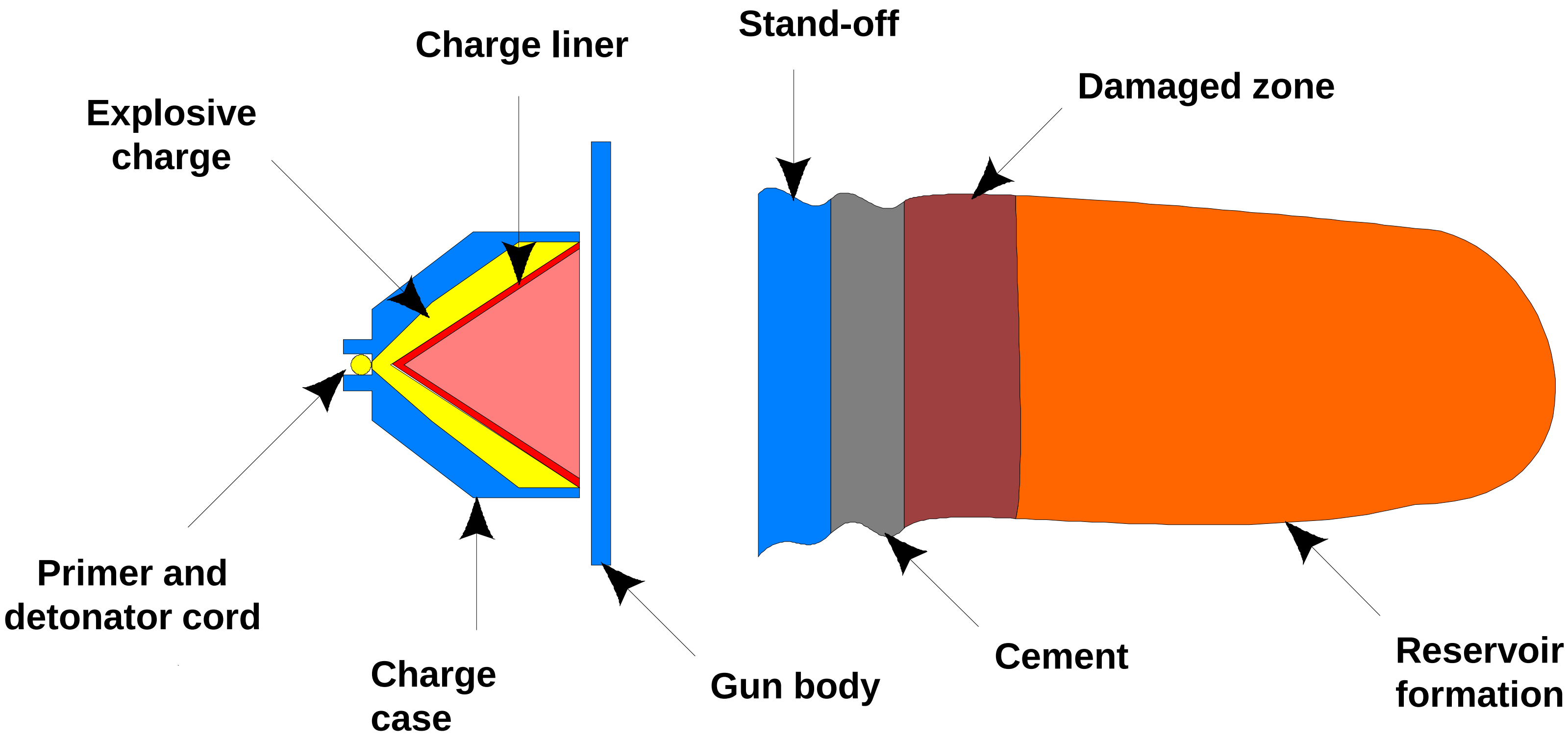
- Location of the perforated interval
- Shot density
- Perforation phasing
- Penetration
- Perforating debris
- Gun conveyance method
- Gun recoverability
- Bottom hole perforating pressure

Perforating Gun Components

Principal perforation gun/system components:

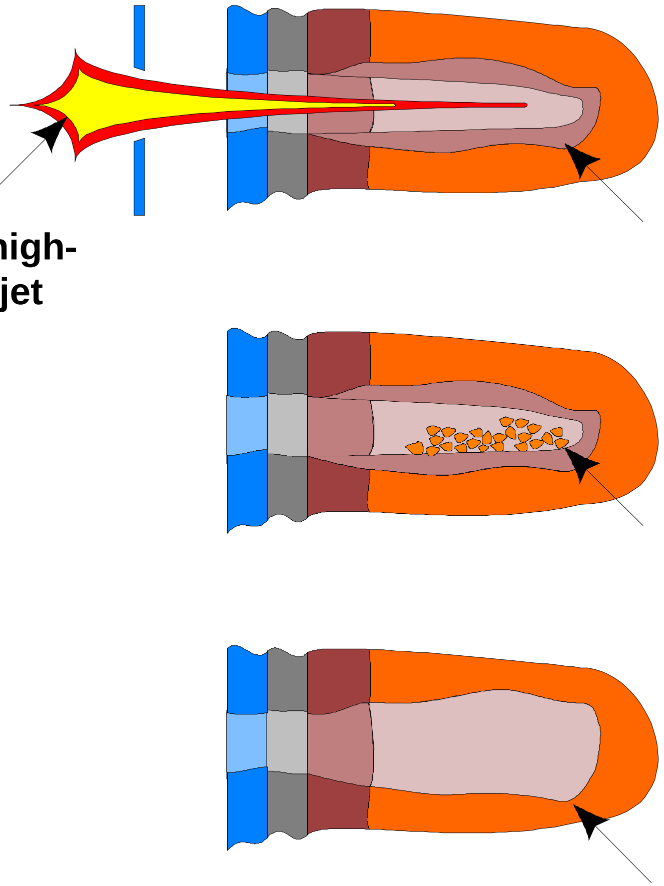
- Charge carrier
  - recoverable, disposable
- Detonator
  - electrical or percussion (dependent on conveyance)
- Detonating cord
  - provides link between charges
- Shaped charge
  - generates high pressure jet

Perforation Charge



Charge components

Perforation Process



Extremely high-pressure jet

Crushed zone

Perforation debris

Clean, stable perforation tunnel

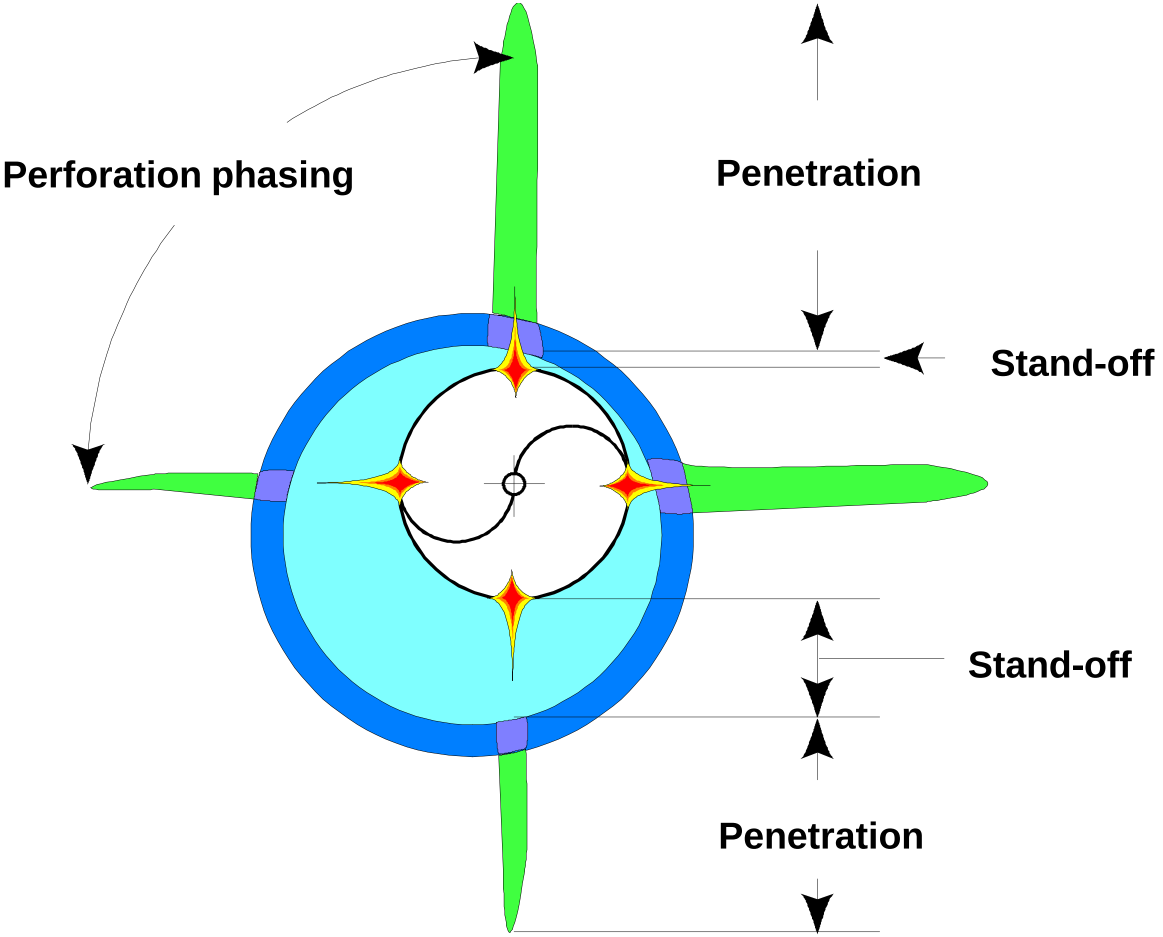
Perforation sequence

Perforating Gun Systems

Perforating gun or system options include:

- Gun conveyance method
  - wireline, TCP or coiled tubing
- Thru-tubing gun systems
  - small OD systems
- Casing gun systems
  - large OD systems
- Tubing conveyed gun systems
  - recovered or dropped
  - suitable for long intervals
  - no verification

Perforation Phasing



Effects of perforation phasing

Perforation Phasing

Perforation phasing describes the angle between shots. Key considerations include:

- Five common configurations - 0^o, 60^o, 90^o, 120^o, 180^o
- phased guns require decentralizing
- Near wellbore flow characteristics effected by phasing
- Oriented phasing may be desirable, e.g., hydraulic fracturing treatments

Penetration, Stand Off and Debris

Penetration - effective length of perforation channel

- Should bypass damaged zone
- Effected by stand-off

Stand Off - distance between gun and casing/liner

- Charge efficiency diminishes with distance
- Effects accentuated at high pressures
- Perforation size effected by stand off

Perforation debris - left in place after perforating

- Some debris inevitable - dependent on gun/charge type
- Should be removed by back flush after/during perforating

Bottomhole Perforation Pressure

Two basic bottom hole pressure conditions associated with perforating:

- Overbalanced - perforating with kill weight fluid column in wellbore
  - Surge following perforation acts to compact debris
  - Requires less complex equipment and techniques
- Underbalanced
  - Removes perforation debris at time of perforation
  - Reduces likelihood of near-wellbore damage
  - Requires special equipment and techniques

A third Pressure condition is being used in the last years:

- Extreme Overbalanced Perforation (EOB); The wellbore pressure in the wellbore is higher than the Frac Gradient.