2014 China International Perforating Symposium
An Independent forum for the advancement of perforating technology

The Development of Selective Perforating Systems

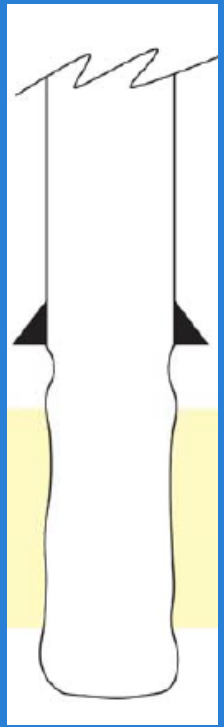
One of the keys to the success of economic shale perforating

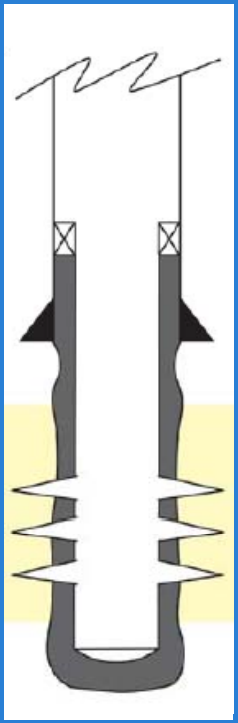
Presented by: Frank Preiss
DynaEnergetics

CIPS-14-008

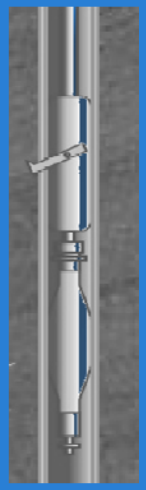
A **DMC** Company

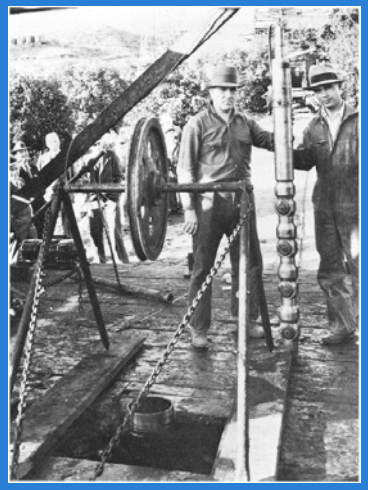
- “Open Hole / Barefoot” completions
- first commercial oil wells drilled in China 347 AD
- drilling from 9th century in Azerbaijan
- first well drilled in North America in 1859
- first exploding torpedoes patented in 1866
- first license from A.Nobel to use dynamite in wells in 1867
- casing completions
    - first casing used for barefoot completions
    - first casing used for well completion late 1800‘s
    - Halliburton develops cemented casing in 1919

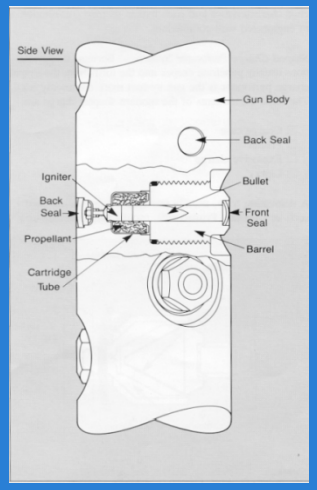


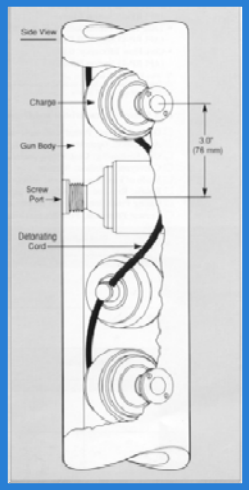


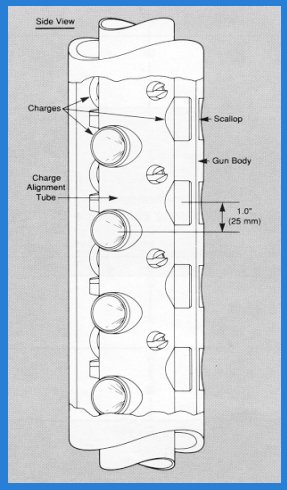
- first mechanical perforator patented in 1910
- gun perforators first patented in 1926
  - have been successfully used since at least 1927
  - early gun perforators were "bullet" devices
  - shaped charges are being used since 1946



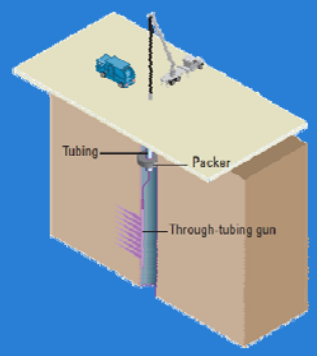


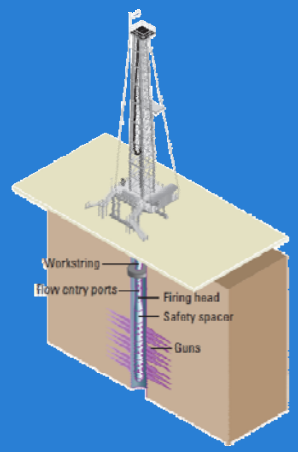


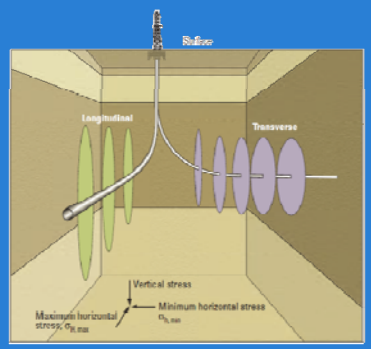


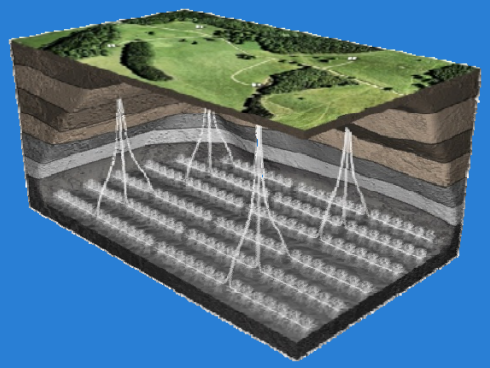


- over time the perforated intervals got longer
- multiple production zones were completed
- historically the majority of wells were vertical
- in the last decades the trend to drill horizontal wells has increased
- the perforating intervals got longer
- operators started to selectively perforate only specific intervals

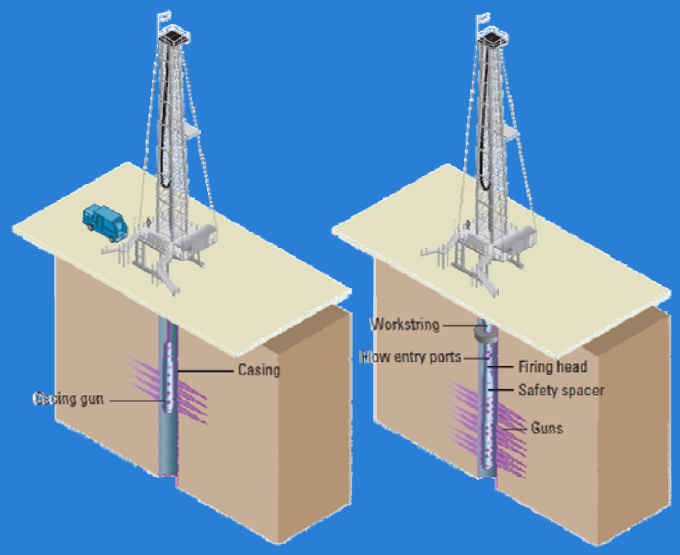




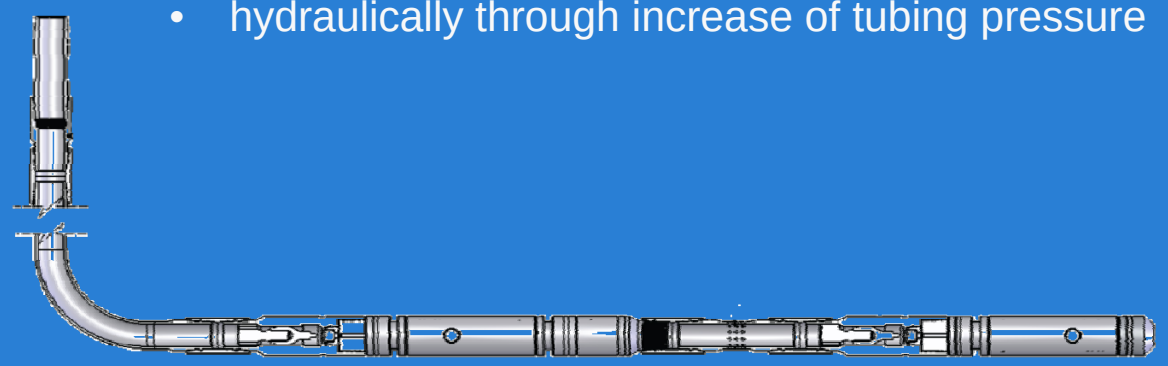




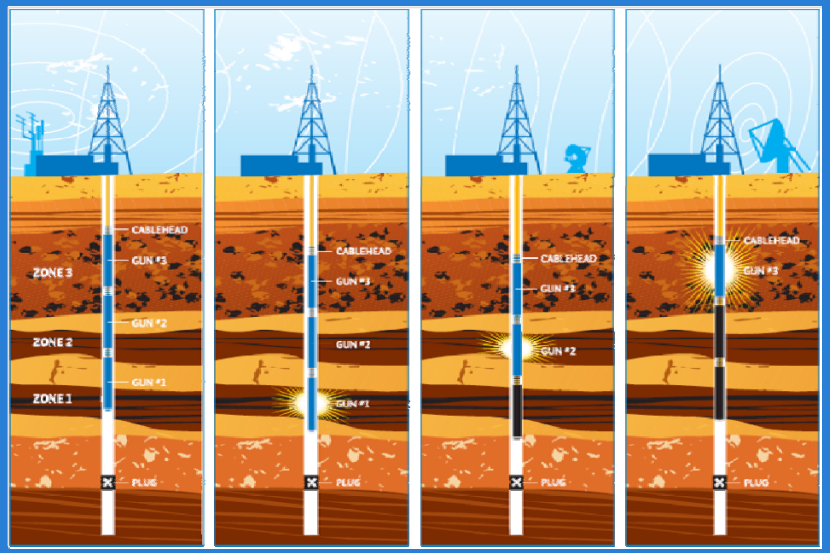
- two conveyance methods for perforating.
  - use of tubing
    - Tubing Conveyed Perforating – TCP
    - Coiled Tubing Perforating
  - use of flexible line
    - electric wireline
    - wire

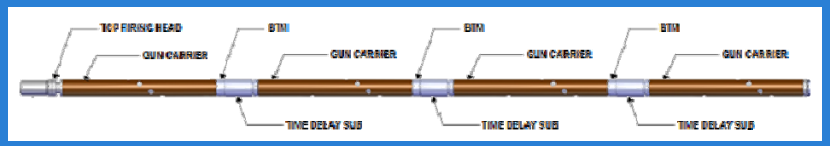


- in TCP
  - the individual guns can be spread out to achieve the desired spacing between differing perforating zones
  - two zones can be perforated independently when two firing heads are used
    - first firing head initiated through annular pressure increase
    - second firing head initiated
      - mechanically through drop bar if well is vertical
      - hydraulically through increase of tubing pressure



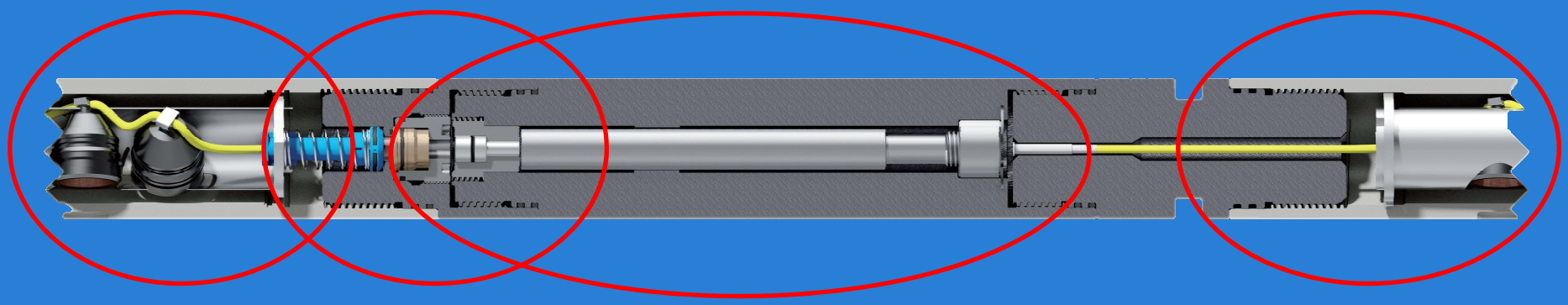
- for multiple zone perforating, time delay devices are used between gun sections
  - perforating string has to be repositioned after each perforation
  - delay time has to be chosen dependent on time needed to reposition the guns

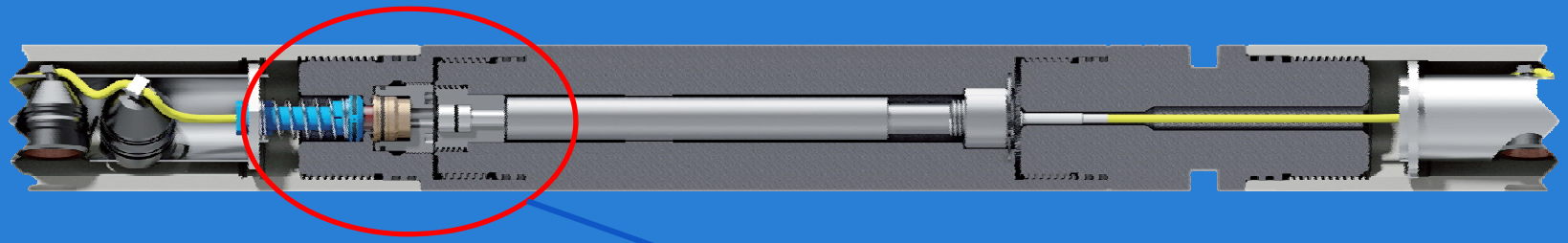




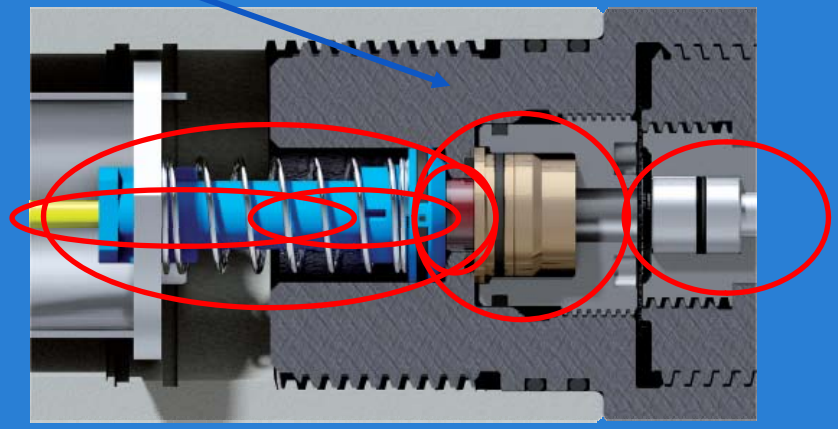
Balistic Transfer Module

- upper and lower perforating gun
- balistic transfer module
  - accommodates the percussion initiator and ballistic transfer to time delay
    - pressure tight after initiation
- time delay sub
  - accommodates the pyrotechnic time delay (6min)



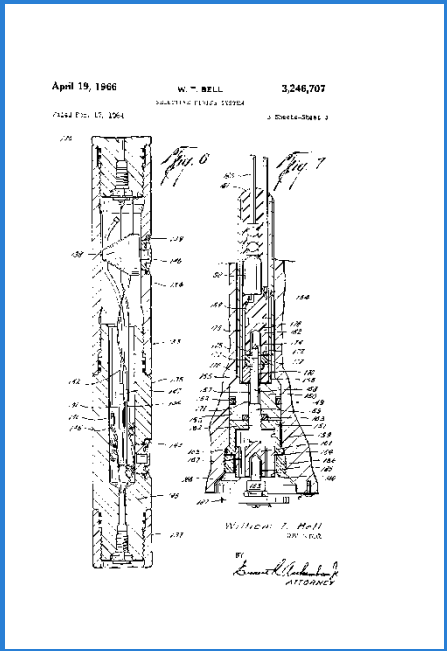


- transfer module sub
- transfer booster kit
- detonating cord
- bi-directional booster
- ballistic output controller
- percussion initiator
- time delay

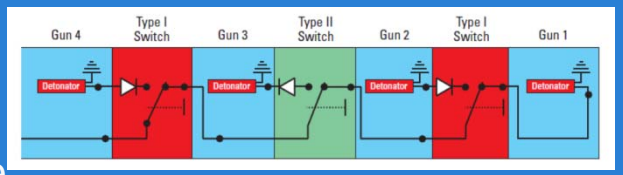


majority of selective perforating is wireline conveyed

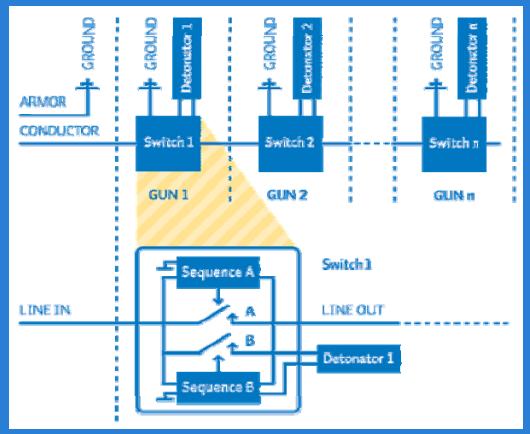
- igniters successively arranged with each succeeding igniter requiring a progressively greater ignition current to fire
- rotary select fire switches was patented in 1964
  - allowed selectively firing multiple guns
  - used rotary switch and pressure activated dart seals
- enhanced dart system introduced in 1970's
  - used diodes in conjunction with the dart seals

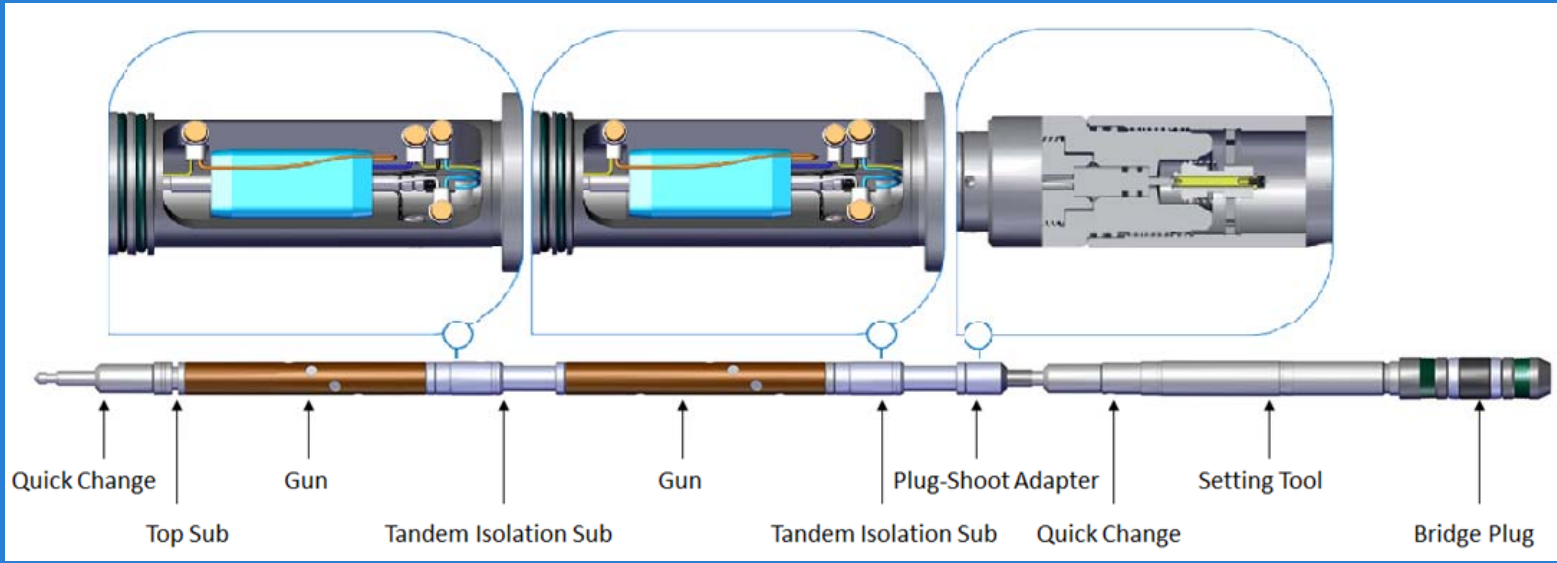


- new generation of pressure activated switches using polarity sensitive diodes introduced in 1980's
  - system uses a pressure activated piston
    - reliability greatly increased and system still used today
    - cost efficient
    - virtually unlimited number of guns can be connected
    - disadvantage of sequential operation
      - must be retrieved from well after misfire
    - No interactive control from surface possible
    - wrong connected diode can result in continued perforating off depth

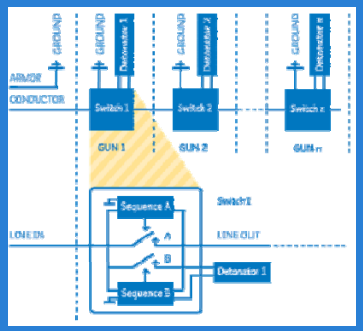


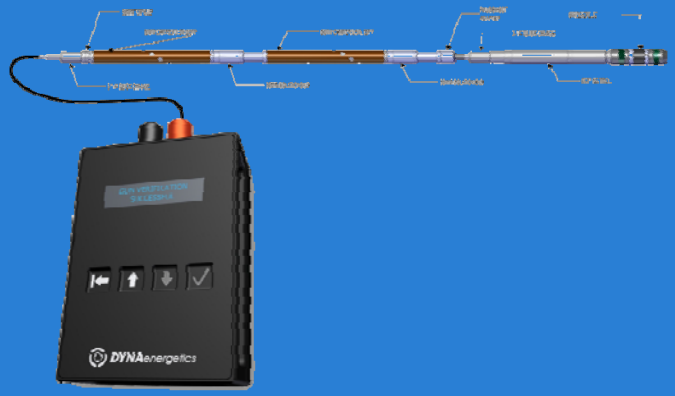
- new idea of selectively perforating on wireline was introduced in 2000
  - eliminate moving parts
  - have active control of the guns downhole
    - done by combining each detonator with electronic selective switch
    - using a surface control panel
    - software for continuous communication to downhole components
  - increased level of safety as detonator is never connected to wireline until specific software command is sent and internal relays is activated
  - next gun does not rely on the previous gun to be shot




Quick Change
Top Sub
Gun
Tandem Isolation Sub
Gun
Tandem Isolation Sub
Plug-Shoot Adapter
Quick Change
Setting Tool
Bridge Plug

- all the selective switch systems available require connection of five wires per gun
  - to assure correct connections surface testers allow assembled guns strings to be tested
    - some testers only test function of the switches, others up to the detonators verifying function
  - all systems offered are tested in accordance with API RP 67





- introduction of more complex systems increased the failure rate potential of perforation operations

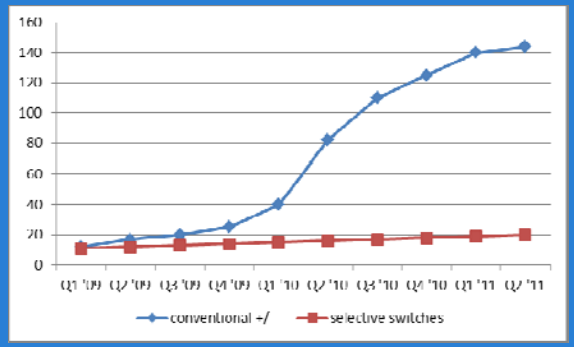
- typical North American shale well site:
  - four well bores
  - twelve stages per well
  - five guns and a plug per stage

    - 48 plugs
    - 240 guns with pressure bulk heads
    - 288 switches
      - over 1.500 electrical connections

    - a huge number of potential failure sources

- **95% -** acceptable efficiency rate for traditional perforation operations (20 runs/misrun)
  - for 48 runs -> 2 misruns or 1/2 day standby
    - at a cost of over $ 600.000 / day (fracking, perforating, other services) in North America) this is $ 300.000

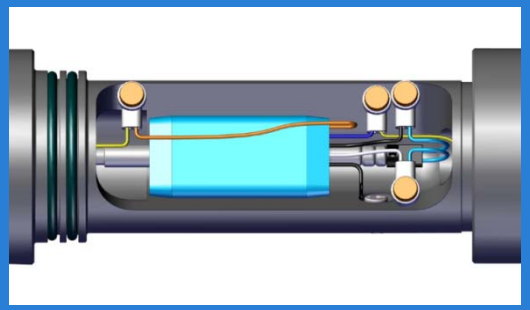
- using selective perforating switches and intensive crew training, one user increased efficiency from 93% to 99% with over 140 runs/misrun
  - although selective systems are more expensive the increase in reliability and efficiency has greatly reduced the overall cost to the oil companies

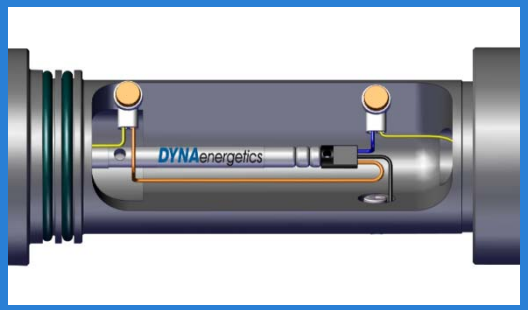


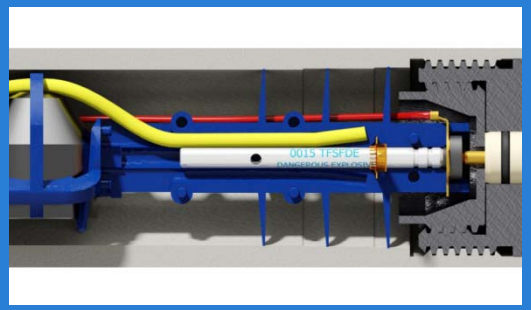
- beside the operational efficiency, safety is a primary concern on shale well sites with parallel perforating and fracking operations
- use of safe perforating systems is highly recommended

- what is safe perforating?
  - rf-safe
  - stray current safe
  - stray voltage safe
  - safe against unintentional initiation
  - functionality and ease of use

- to further enhance the efficiency the first safe integrated switch detonator was introduced in 2012
  - incorporates the selective switch into the detonator housing
  - number of connections per gun are reduced by 40% (from 5 to 3)
- third party tested for being intrinsically RF, stray voltage and current safe
- a top fire safe integrated switch detonator was patented in 2014
  - elimination of wire connections







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