Safe Perforating Technologies in Today's Complex Perforating Environment

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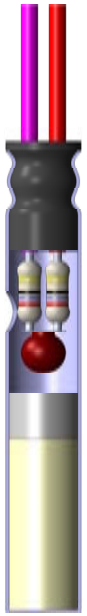
Complex Perforating Environment

- E-line pump down and e-coil operations dominate the horizontal shale completions in North America

- Dozens of personnel from different service companies with varying experiences levels on one location

Electro-Explosive Devices (EED)

- EED: An explosive component that initiates an explosive train and is activated by electric current or a current pulse.
- Examples: electric detonator and igniter
- Electric detonators come in various forms with different firing specifications and energy immunity levels



Electro-Explosive Devices (EED)

- The electric detonator is most susceptible to hazards during arming and disarming procedures

- The explosive user in charge must eliminate all hazards prior to arming and disarming procedures

Potential Hazards: Electrical Energy

- **Electro-static Discharge (ESD):** Human body, contact with charged object, electrical storm

- **Stray Voltage:** Any potential difference between wellhead and rig, and wellhead and perforating unit.

- **Radio Frequency Transmitters:** Cell phones, GPS systems, radar, 2-way radios, WIFI, radio towers

- **Power Sources:** Electric welding, cathodic protection systems, top drive system, generators, power lines

❖ **Direct Voltage**: Voltage applied to the e-line by human error and negligence on surface

Controlling Potential Hazards

- **Explosive Safety Placard:** Procedure for field explosive operations to eliminate/reduce any hazards

EXPLOSIVES SAFETY PLACARD

Conventional Electrical Detonators

1. Hold consultation with client, if possible.
2. Check well area for hazards and correct when necessary.
3. Hold spot safety meeting.
4. No smoking except in designated areas. Smoking materials must be stored when leaving these areas.
5. Rig up cable. Remove rig wiring that might contact cable. Top drive systems should be electrically isolated in accordance with the manufacturer's procedures.
6. Outside preparations before attaching an explosive device:
   a. Turn off electrical cathodic protection systems.
   b. Discontinue all electric welding operations.
   c. On water operations, install the positive grounding cable from truck to barge or wireline unit to generator skid.
   d. Check voltage between the rig, casing and cable armor. Eliminate at source, if present.
   e. Test and install Casing-to-Rig Voltage Monitor.
   f. If voltage is not zero, attempt to eliminate it. DO NOT PROCEED WITH OPERATIONS IF RESIDUAL VOLTAGE IS IN EXCESS OF 0.25V.
   g. Install safety grounding straps between the unit, rig and casing.
   h. Put out sign reading "Danger Explosives - Turn Off Radio Transmitters" or equivalent.
   i. Turn off all transmitters (radio, cellular, radar, etc.) within 1000 feet of the well. Receiving units located within the established safe distance must be disabled such that an incoming call cannot activate the transmitter. If any receiver or transmitter must remain enabled, contact your Operations Manager.
   j. If well is within 5 miles of a large transmitter (radio or TV station) or within 200 feet (70 meters) of high voltage (>10kv) power lines, contact your Operations Manager.
7. WARNING - "HOTCHECKS" (passing current through a cable, head and CCL, or applying voltage to the cable) are permitted only on the condition that the cable head is brought into the logging cab. No power is to be applied through a gun or explosive tool assembly at any time while on the surface, ARMED OR UNARMED.
8. Instrument cab preparations for explosive operations:
   a. Ensure continuity of logging cable to safety switch (CSS). Do not disconnect collector plug.
   b. Turn off all AC powered instrumentation according to instrument cab instructions. This should include main circuit breakers, inverters, UPS's, AC generators and rig power. AC power can ONLY be left connected to necessary safety systems (safety pressurization systems, fire and gas detection systems and electric winch motive power).
   c. Turn off safety switch (CSS) and remove key. The key MUST remain outside the wireline unit until the explosive device is introduced into the well to a minimum depth of 200 feet (70 meters) below ground level or the sea floor.
9. Procedure for attaching any explosive device (such as CST, perforating guns, etc.) to the cable:
   a. Arming or disarming a gun must not be attempted during a thunderstorm, dust storm, sandstorm or during the arrival of helicopters or boats at an offshore site. Arming procedures must not be commenced if such weather is expected to arrive before the arming operation can be completed and the gun introduced into the well to a minimum depth of 200 feet (70 meters) below ground level or the sea floor.
   b. Verify that Casing-to-Rig Voltage Monitor is reading less than 0.25V.
   c. Clear line of fire of all personnel.
   d. Attach explosive device to the head or collar locator. The individual performing the operation MUST have the safety switch key in his/her possession at the time. The key is to remain outside the wireline unit until the explosive device is introduced into the well to a minimum depth of 200 feet (70 meters) below ground level or the sea floor.
10. Arming perforating guns (ONLY THE ENGINEER OR TECHNICIAN IN CHARGE OF JOB MAY ARM A GUN):
    a. The cable must be attached to the gun string before the gun string is armed. However, guns that are not electrically connected to the cable when the head is attached may be armed immediately prior to their use and then attached to the cable.
    b. Confirm that line of fire is still clear.
    c. Check gun wires for sparking.
    d. Trim gun wires and trim detonating cord.
    e. Insert blasting cap in Blasting Cap Safety Tube. Close and secure cap of tube.
    f. Connect blasting cap wires to gun lead wires.
    g. Remove blasting cap from Safety Tube and crimp to detonating cord using Blasting Cap Crimping Pliers or insert blasting cap in booster holder. Store all explosive remnants.
    h. Prepare gun to run in hole.
11. Proceed into well.
12. Safety procedure in hole:
    a. At a minimum depth of 200 feet (70 meters) below ground level or the sea floor, turn on safety switch, restore ACpower, etc. Continue in hole.
    b. Tie in, position gun and shoot.
    c. Come out of hole. At a minimum depth of 200 feet (70 meters) below ground level or the sea floor, prepare the instrument cab as for explosives operations (8.a. through c.) and verify that the casing-to-rig voltage is less than 0.25V. CAUTION - If a thunderstorm, dust storm or sandstorm threatens to arrive before the disarming operation can be completed, the gun must be kept in the well at a minimum depth of 200 feet (70 meters) below ground level or the sea floor.
13. If the gun(s) did not fire immediately disarm ballistically the electrically connected gun(s) (using the procedure prescribed in the Field Operations Manual) BEFORE the gun is disconnected from the cable.
14. All guns must be safelyrelieved of any trapped pressure immediately upon removal from well according to the instructions in the Field Operations Manual.
15. Check the area for detonating cord remnants, charges, etc., and pack them in the explosives remnants box.

Controlling Potential Hazards

- Controlling potential energy hazards is time consuming and costly
- Add possible human error to the already complex perforating environment
- Safe perforating technology should be implemented

Safe Technology: Safe Initiating Systems

Examples:

- Exploding Bridge Wire (EBW) detonator
- Exploding Foil Initiator (EFI) detonator
- Semiconductor Bridge Element (SCB) detonator

Safe Technology: Safe Initiating Systems

Features:

- Designed such that substantially higher input current or power is required to activate the detonator
- Contains no primary high explosive

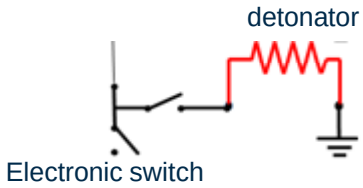
Benefits:

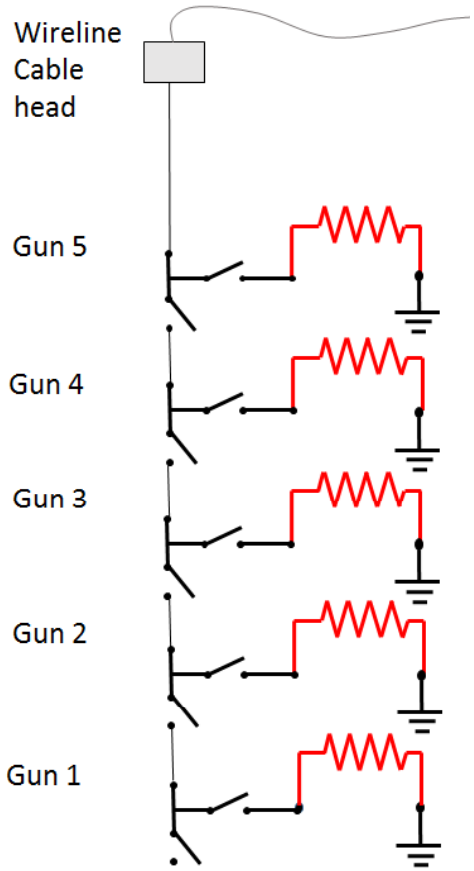
- Immune to radio frequencies and stray voltages common to the well site
- Less sensitive to impact shock

Safe Technology: Electronic Switch/Detonating Systems

Examples:

- Electronic switch embedded in or assembled to specified detonator





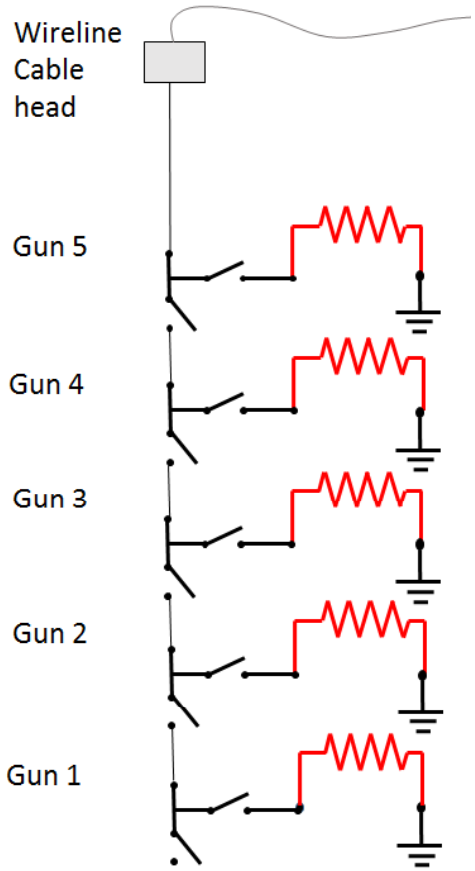
Safe Technology: Electronic Switch/Detonating Systems

Features:

- Designed such that detonator is not electrically armed until specified electrical signal is given from surface.

Benefits:

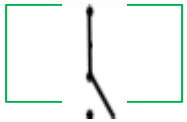
- Immune to radio frequencies and stray voltages common to the well site
- Can block direct voltage caused by human error/negligence on surface



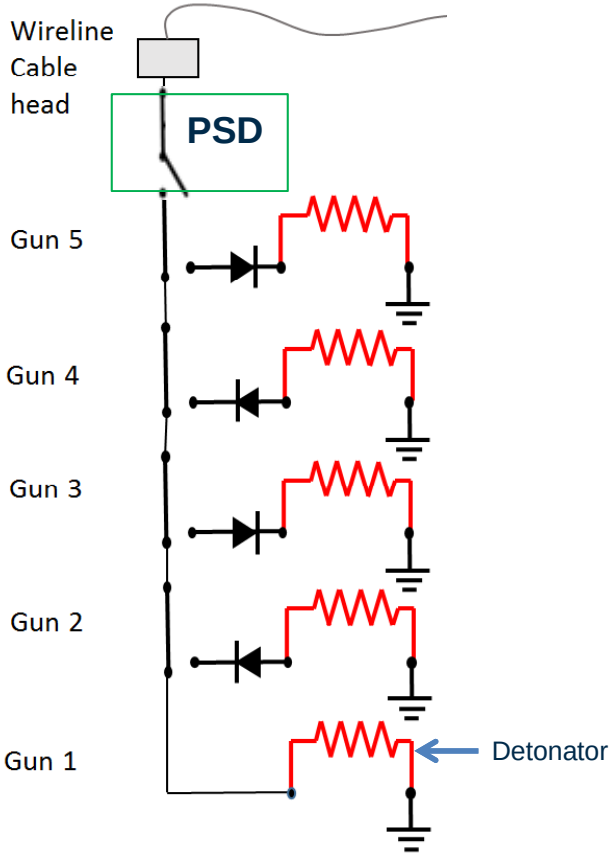
Safe Technology: Power Safe Devices

Examples:

- Perforating safety subs, voltage protection modules
- Non explosive electronic switch



PSD



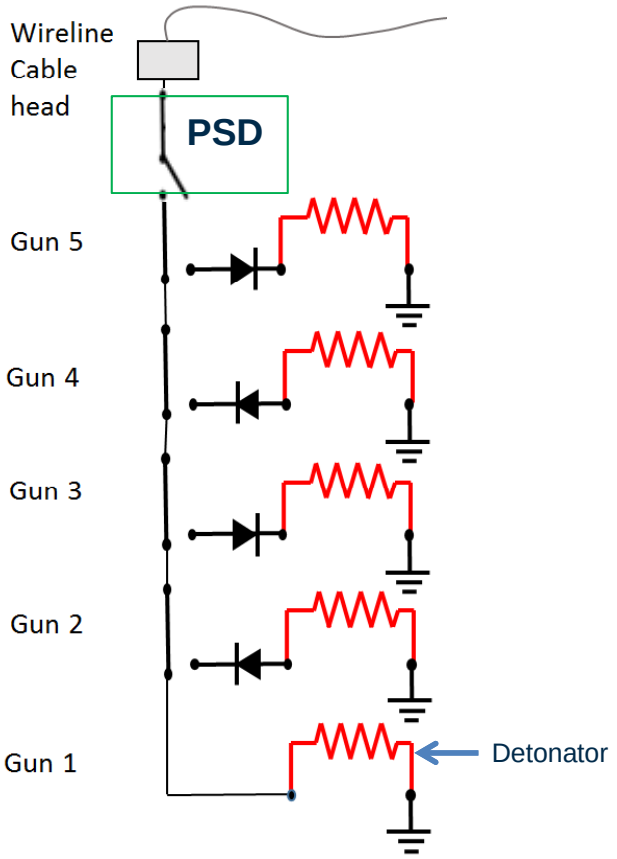
Safe Technology: Power Safe Devices

Features:

- Designed to isolate downhole explosive devices from any power generating devices above it or on surface
- Electrical connection to explosive device activated by specific sequence of events

Benefits:

- Can block direct voltage caused by human error/negligence on surface



Cost of Safety

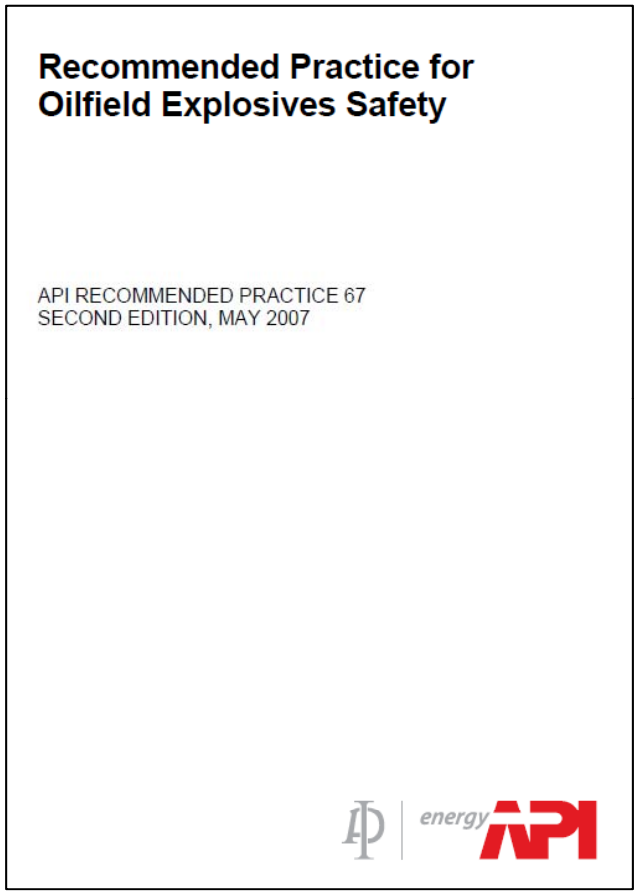
- Implementation of safe perforating technology can increase the perforating costs by 10-30% depending on which system(s) used.

- By implementing safe initiating systems and/or electronic switch/detonating systems, there is considerable time savings because radio silence is avoided.
  10 stages * 5 wells = 50 runs * 1 hr RF control time per run = 50 hrs NPT

- Cost of non-productive time for radio silence to the operator may exceed the extra costs associated with running safe perforating technology.

Explosives Safety Education

- Explosives safety training is imperative due to the growing number of inexperience personnel
- Manufacturers are willing and available to put on RP-67 classes
- Educate operators and service companies on the safe perforating technologies available



Conclusion

- Today's complex perforating environment poses several hazards that can increase the likelihood of a perforating accident.
- The Explosive User in Charge may not be able to control all hazards and is susceptible to human error.
- Safe perforating technologies exist that protect against known hazards and even human error.
- The time savings associated with implementing safe perforating technology can outweigh the extra costs.
- Due to a growing inexperienced oilfield, explosives safety training and safe perforating technology is imperative for safe perforating operations.

References

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- Photograph of shaped charge jet. James Cole. Hunting, 2014.
- Selective switch diagrams. Courtesy of Bob Ference.
- EBW, EFI and SCB detonator images from Google Images

Questions?