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Casing Perforating Overview

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devon

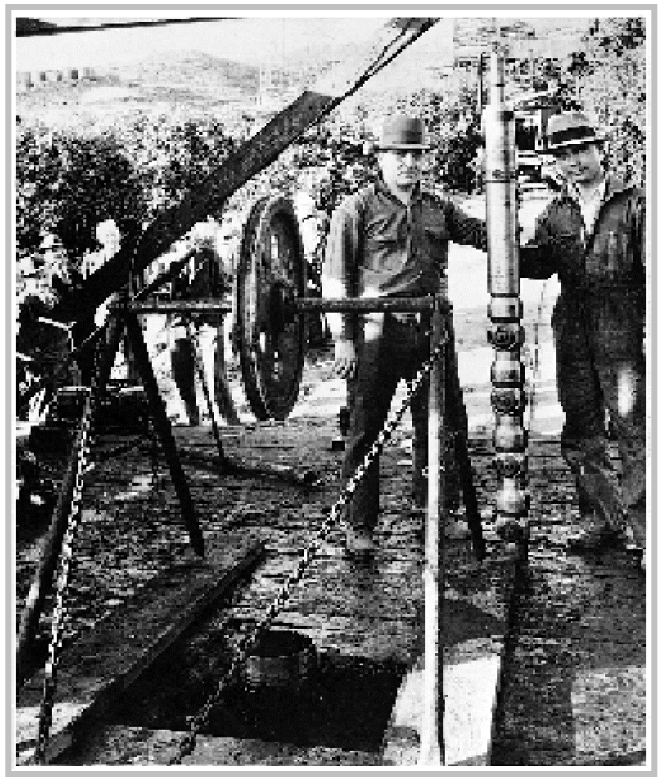
Perforating Objective

- The primary objective of a perforating gun is to provide effective flow communication between a cased wellbore and a productive reservoir.

- To achieve this, the perforating gun “punches” a pattern of perforations through the casing and cement sheath and into the productive formation.

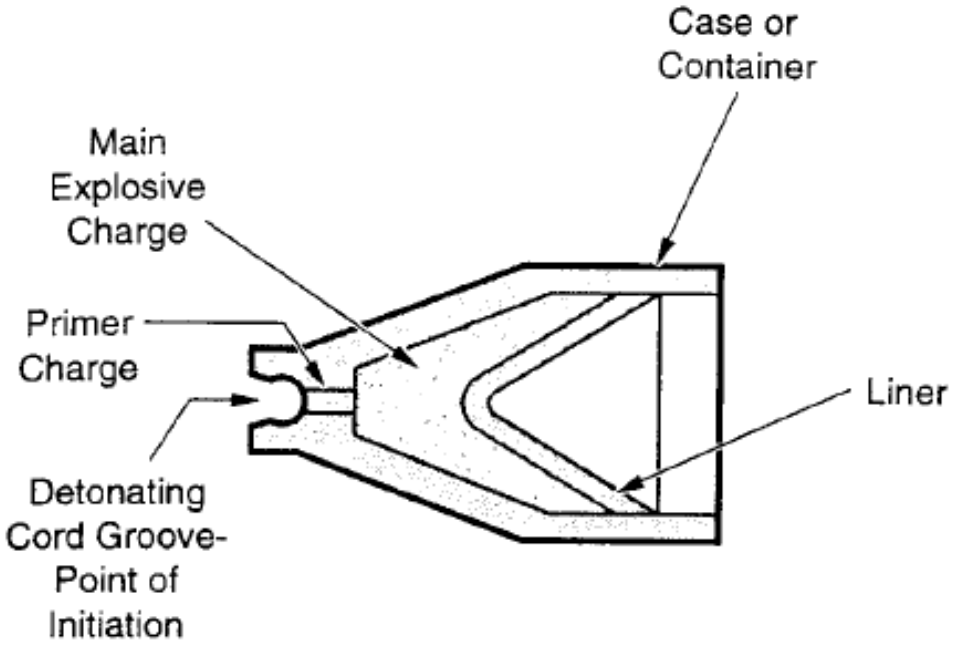
First Bullet Perforating - 1932

Lane Wells Company, Unit #1

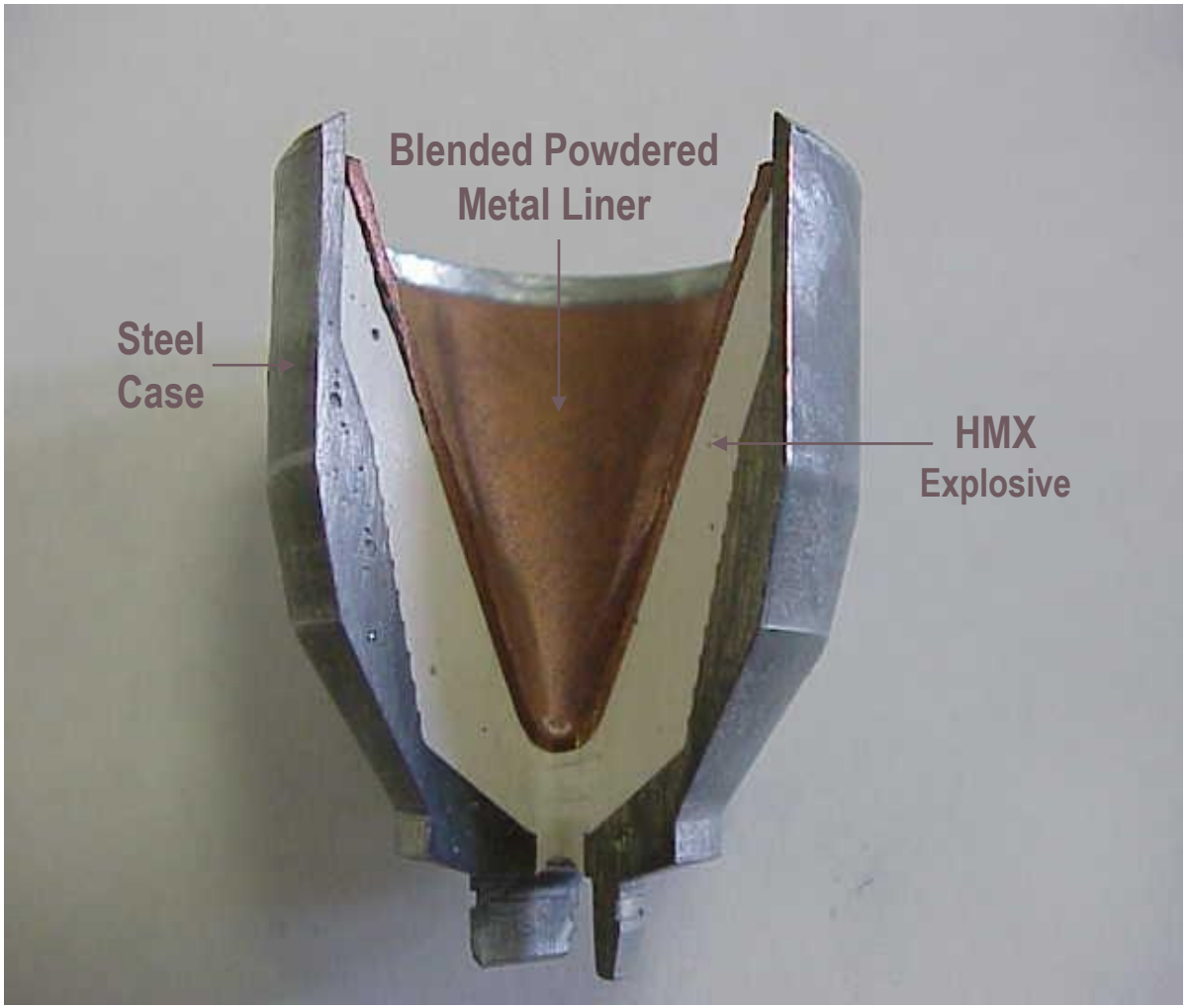


First Perforating Job

Shaped Charge Components

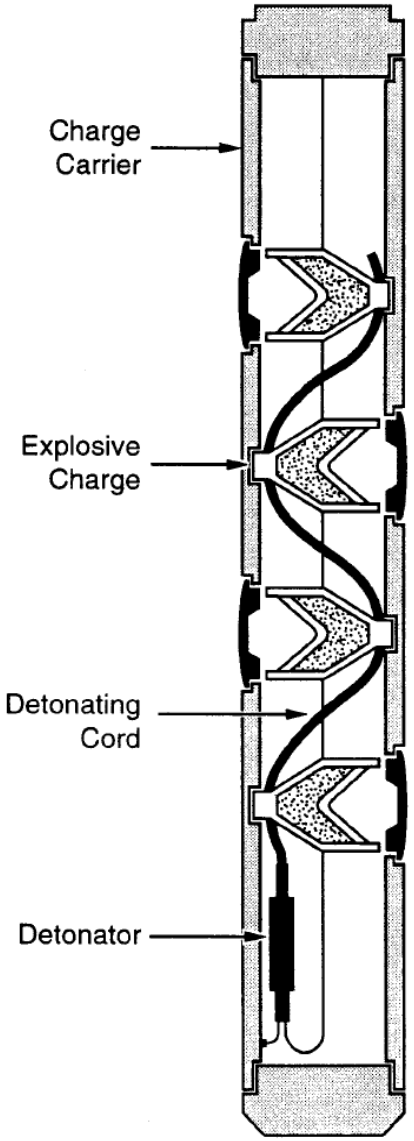


Typical Shaped Charge



Perforating Gun Components

- The Perforating Gun has four components
  - A conveyance for the shaped charge
  - The individual shaped charge
  - Detonating cord
  - Detonator



Explosives Used for Shaped Charges and Detonator Cord

- RDX (Cyclotrimethylene Trinitramine) Good to 330 degrees F
- HMX (Cyclotetramethylene Trinitramine) Good to 400 degrees F
- HNS (Hexanitrosilbene) Good to 520 degrees F
- Each shaped charge will contain between 3 to 60 grams of explosives

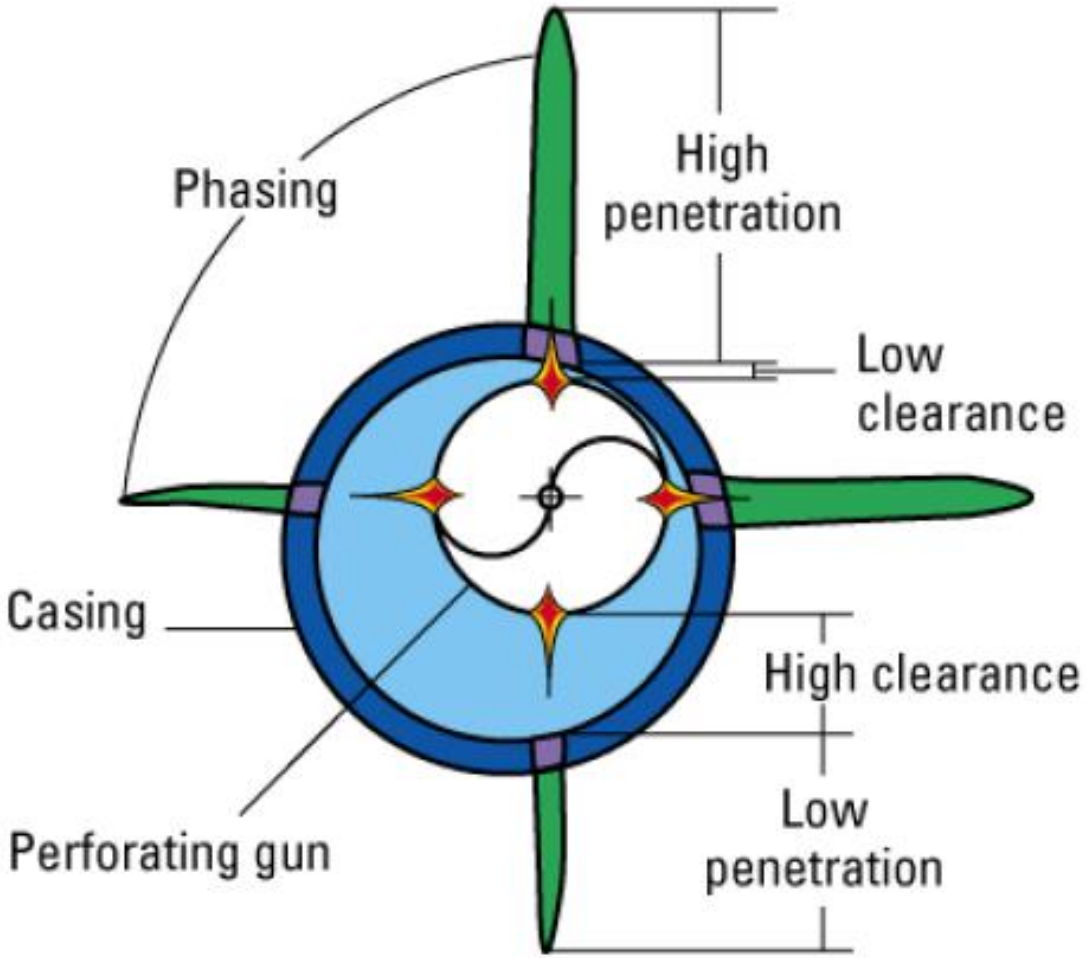
Shaped Charge Perforating

- When detonated, the perf guns go off instantaneously.
- The leading tip of the jet has a velocity of 25,000 to 30,000 ft/sec.
- The impact pressure is approximately 10 to 15 million psi.
- This pressure overcomes casing and formation strength and forces material radially away from the jet axis.

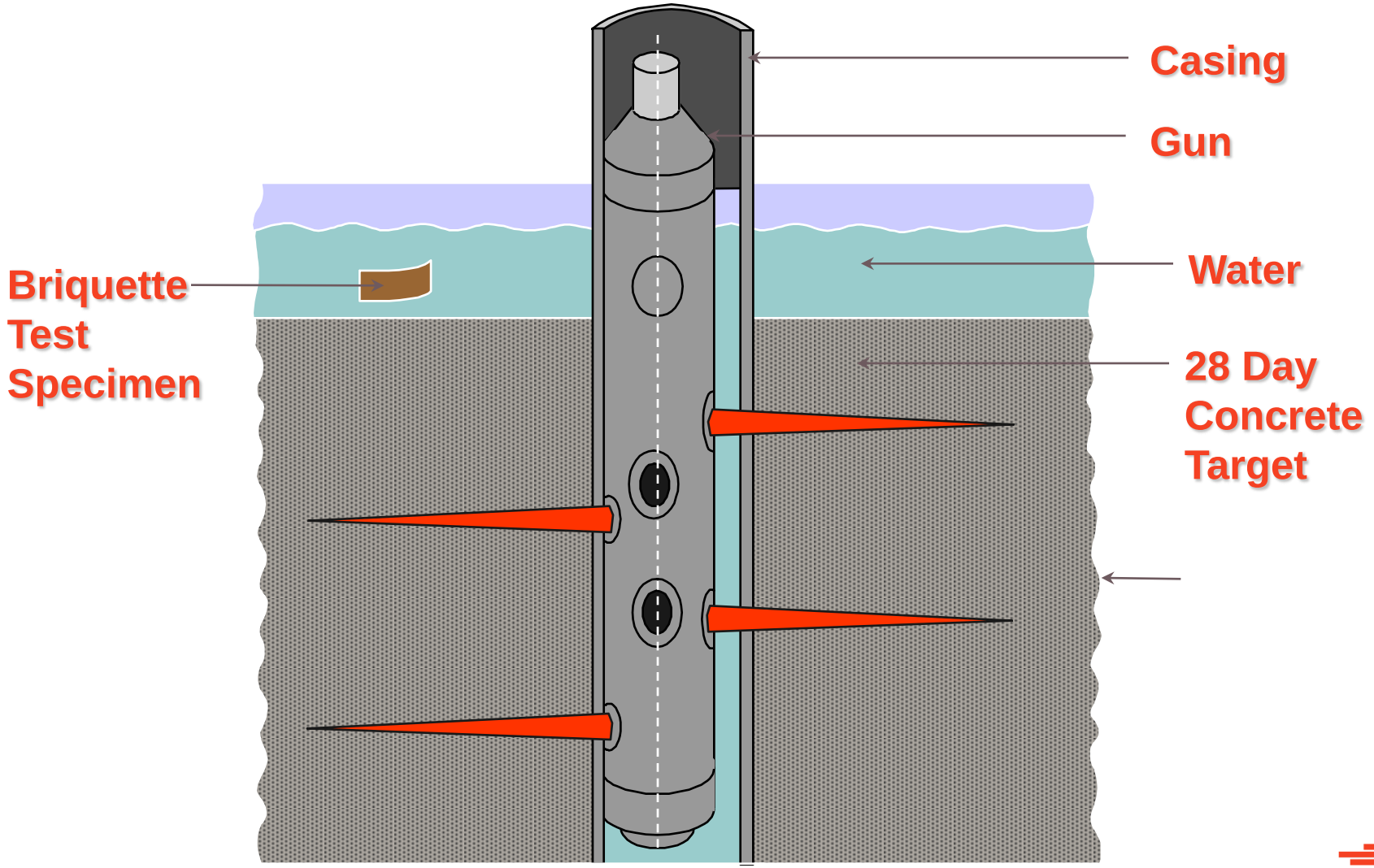
Perforating Guns

- Most perforating guns punch holes from 0.23” to 0.72” in diameter.
- Typical perf guns have penetrations of 6” up to 48” in length.
- Most perforating guns shoot from 4 to 12 shots per foot.
- Perf guns come in different pressure and temperature ratings.

Perforation Geometry



API RP19B Section 1 Test



Example of Perf Charges from a 3-3/8” Gun

From an API RP19B Section 1 Test

Example of one Company's Perforating Gun Performance Chart

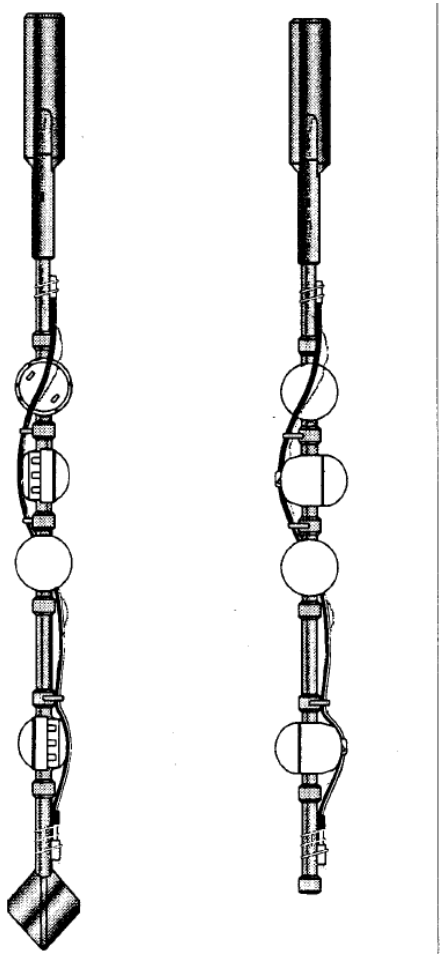
GUN CONFIGURATION			PERFORMANCE DATA API-RP 43 SECTION I Edition 5						CHARGE INFORMATION					CARRIER	
Gun OD (in.)	Shot Density (spf)	Phase (deg.)	Avg. Entry Hole Dia. (in.)	Avg. Pen. (in.)	Target Strength (psi)	Casing OD (in.)	Casing Weight (ppf)	Casing Grade	Expl. Type	Expl. Weight (gms.)	Charge Name	Charge Case	Charge Part No.	Pressure Rating (psi)	Min. ID for Running (in.)
1-9/16	4	0/60/90/180	0.23	8.4	7025	4-1/2	11.6	L-80	RDX	3.0	AJ	Steel	142327-000	20,000	1.78
1-9/16	4	0/60/90/180	0.24	8.8	6610	4-1/2	11.6	L-80	HMX	3.0	AJ	Steel	142327-004	20,000	1.78
1-9/16	4	0/60/90/180	0.20	11.0	7544	4-1/2	11.6	L-80	HMX	3.0	Predator	Steel	142327-504	20,000	1.81
2	4 or 6	0/60/90/180	0.28	12.2	8090	4-1/2	11.6	L-80	RDX	6.5	AJ	Steel	154910-000	20,000	2.25
2	4 or 6	0/60/90/180	0.26	12.8	7200	4-1/2	11.6	L-80	HMX	6.5	AJ	Steel	154910-004	20,000	2.25
2	4 or 6	0/60/90/180	0.24	21.4	6287	4-1/2	11.6	L-80	HMX	6.5	Predator	Steel	154910-504	20,000	2.27
2	6	60	0.22	20.6	6784	4-1/2	11.6	L-80	HMX	6.5	Predator	Steel	154910-504	20,000	2.27
2-3/4	6	60	0.27	16.5	6420	4-1/2	11.6	L-80	RDX	10.5	AJ	Steel	144528-100	20,000	3.00
2-3/4	6	60	0.30	18.1	7040	4-1/2	11.6	L-80	HMX	10.5	AJ	Steel	144528-104	20,000	3.00
2-3/4	6	60	0.28	23.2	8698	4-1/2	11.6	L-80	HMX	15.0	Predator	Steel	144528-504	20,000	3.10
2-7/8	6	60	0.28	27.2	7476	4-1/2	11.6	L-80	HMX	16.0	X-Jet	Perfform	06-79931-11	22,000	3.25
2-7/8	6	60	0.28	26.5	7476	4-1/2	11.6	L-80	HMX	16.0	X-Jet	Steel	06-79931-01	22,000	3.25
2-7/8	6	60	0.34	13.6	6330	4-1/2	11.6	L-80	RDX	16.0	DP	Steel	06-77507-00	22,000	3.25
2-7/8	6	60	0.33	12.7	5350	4-1/2	11.6	L-80	HMX	16.0	DP	Perfform	06-77507-11	22,000	3.25
3-3/8	4	90	0.48	22.8	8400	4-1/2	11.6	L-80	RDX	21.0	AJ	Steel	159559-000	20,000	3.80
3-3/8	4	90	0.46	23.7	7930	4-1/2	11.6	L-80	HMX	21.0	AJ	Steel	159559-004	20,000	3.80
3-3/8	4	90	0.46	25.2	7400	4-1/2	11.6	L-80	RDX	28.0	AJ	Steel	151178-000	20,000	3.80
3-3/8	4	90	0.48	25.8	5250	4-1/2	11.6	L-80	HMX	28.0	AJ	Steel	151178-004	20,000	3.80
3-3/8	4	90	0.47	36.5	7037	4-1/2	11.6	L-80	HMX	32.0	Predator	Steel	151178-504	20,000	3.80
3-3/8	6	60	0.36	19.7	6570	5-1/2	17.0	L-80	RDX	23.0	DP	Perfform	06-78126-10	20,000	3.75
3-3/8	6	60	0.31	20.1	7595	5-1/2	17.0	L-80	HNS	23.0	DP	Steel	06-78126-02	20,000	3.75
3-3/8	6	60	0.39	22.1	7030	5-1/2	17.0	L-80	RDX	23.0	DP	Steel	06-78126-00	20,000	3.75
3-3/8	6	60	0.47	22.8	8640	4-1/2	11.6	L-80	RDX	21.0	AJ	Steel	159559-000	20,000	3.80
3-3/8	6	60	0.46	23.9	8130	4-1/2	11.6	L-80	HMX	21.0	AJ	Steel	159559-004	20,000	3.80
3-3/8	6	60	0.47	33.9	7288	4-1/2	11.6	L-80	HMX	22.0	Predator	Steel	159559-504	20,000	3.80
3-1/2	4	90	0.40	39.4	5385	5	15.0	L-80	HMX	32.0	Predator	Steel	151178-504	20,000	3.95
3-1/2	5	60	0.43	37.7	6606	5	15.0	L-80	HMX	32.0	Predator	Steel	151178-504	20,000	3.95
4	4	90	0.50	32.0	7780	5-1/2	17.0	L-80	RDX	32.0	AJ	Steel	150040-000	20,000	4.70
4	4	90	0.49	36.9	7620	5-1/2	17.0	L-80	HMX	32.0	AJ	Steel	150040-004	20,000	4.70
4	4	90	0.49	42.5	7776	5-1/2	17.0	L-80	HMX	38.5	Predator	Steel	190680-504	20,000	4.70

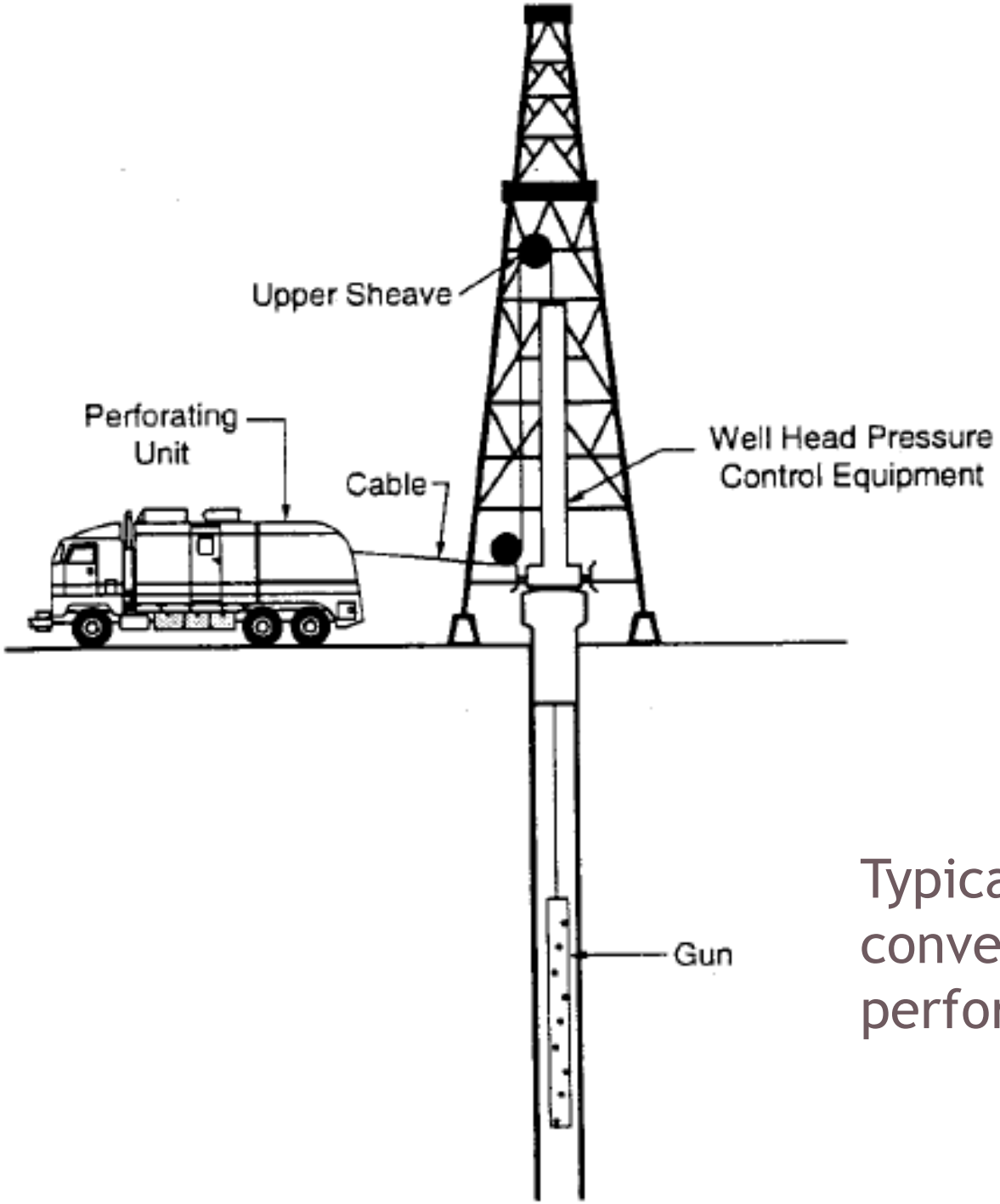
Hollow Carrier Gun

- Charges are carried in a heavy wall tube.
- Charges are sealed from wellbore fluid and pressure.
- Most of the debris from the charge remains in the carrier.
- Detonation only slightly swells the gun but not enough to affect recovery from the well.

Expendable Shaped Charge Gun

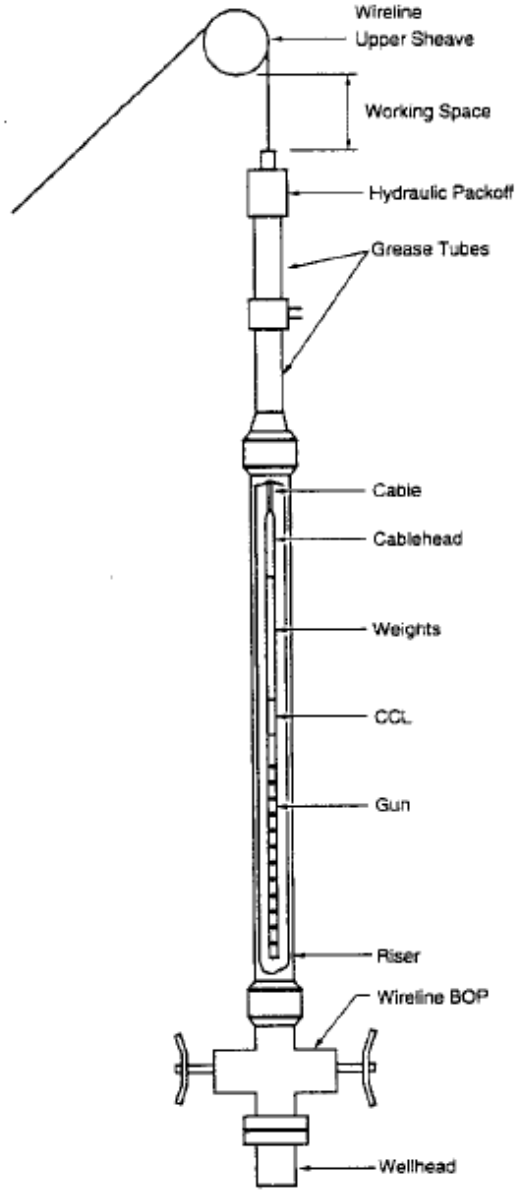
- Charges can be larger than the charges for the same diameter hollow carrier gun.
- Charges are individually sealed from the wellbore environment.
- The Detonator cord and detonator are exposed to wellbore fluids.
- Much of the debris is left in the well, falling into the rat hole on vertical wells.





Typical Wireline conveyed perforating hookup

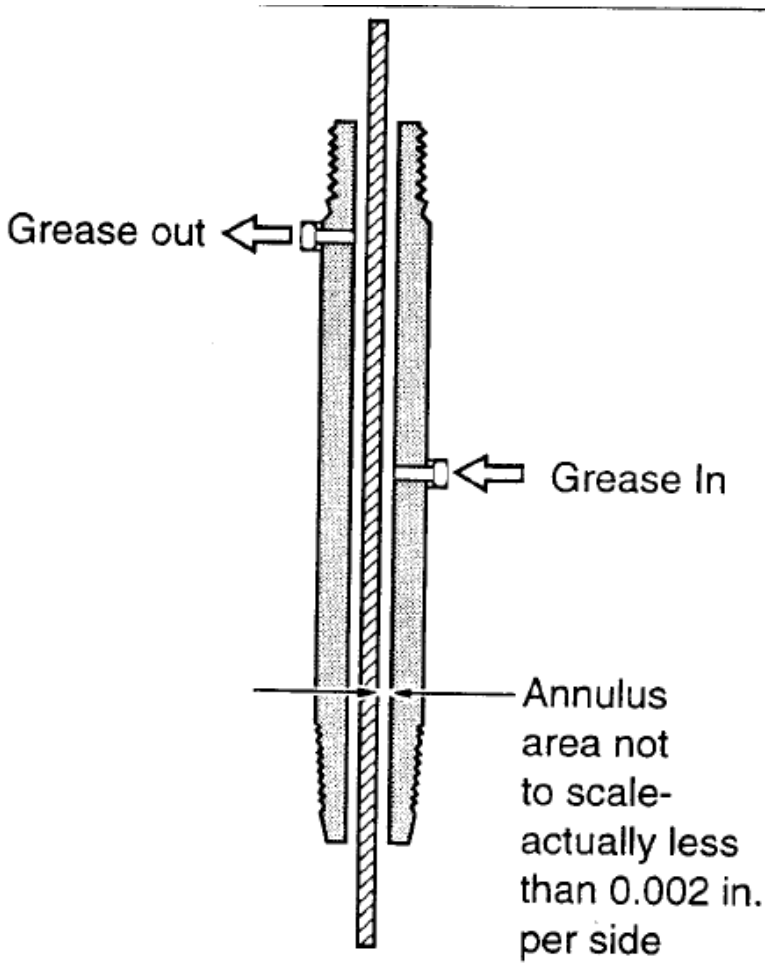
Wireline Pressure Control Equipment Configuration. The Pressure Control Equipment is commonly known as a Lubricator.



Control Head

- Control Heads are the uppermost point of the lubricator string, where the wireline enters the lubricator system. Well pressure is controlled with packing, pack-off rubbers, grease injection or a combination of all.

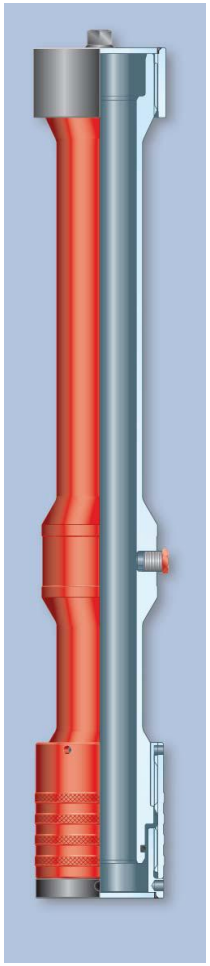
Wireline Passing Through Grease-Seal Flow Tube



Lubricator or Riser Section

The lubricator or riser section is used to allow the full wireline tool string to be raised above the wellhead before and after the operations.

The length of lubricator required is proportionate to the length of the wireline tool string.



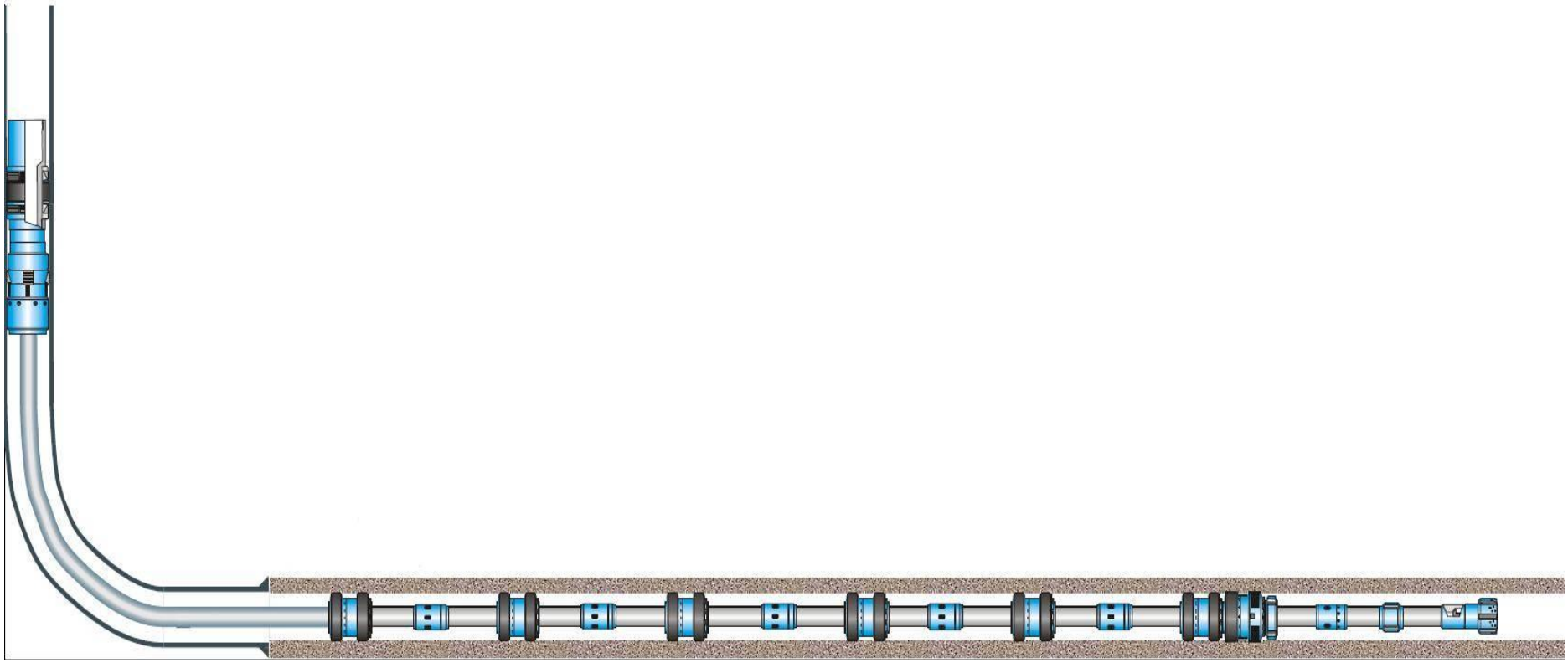
Depth Correlation

- A cased hole gamma ray / casing collar locator log are run for correlation purposes to assist in perforating depth control.
- Short joints of casing are sometimes run to assist in the correlation.
- The distance from the top shot of the gun to the casing collar locator is measured before running the perforating system in the well to ensure the perforations are placed where they were intended.

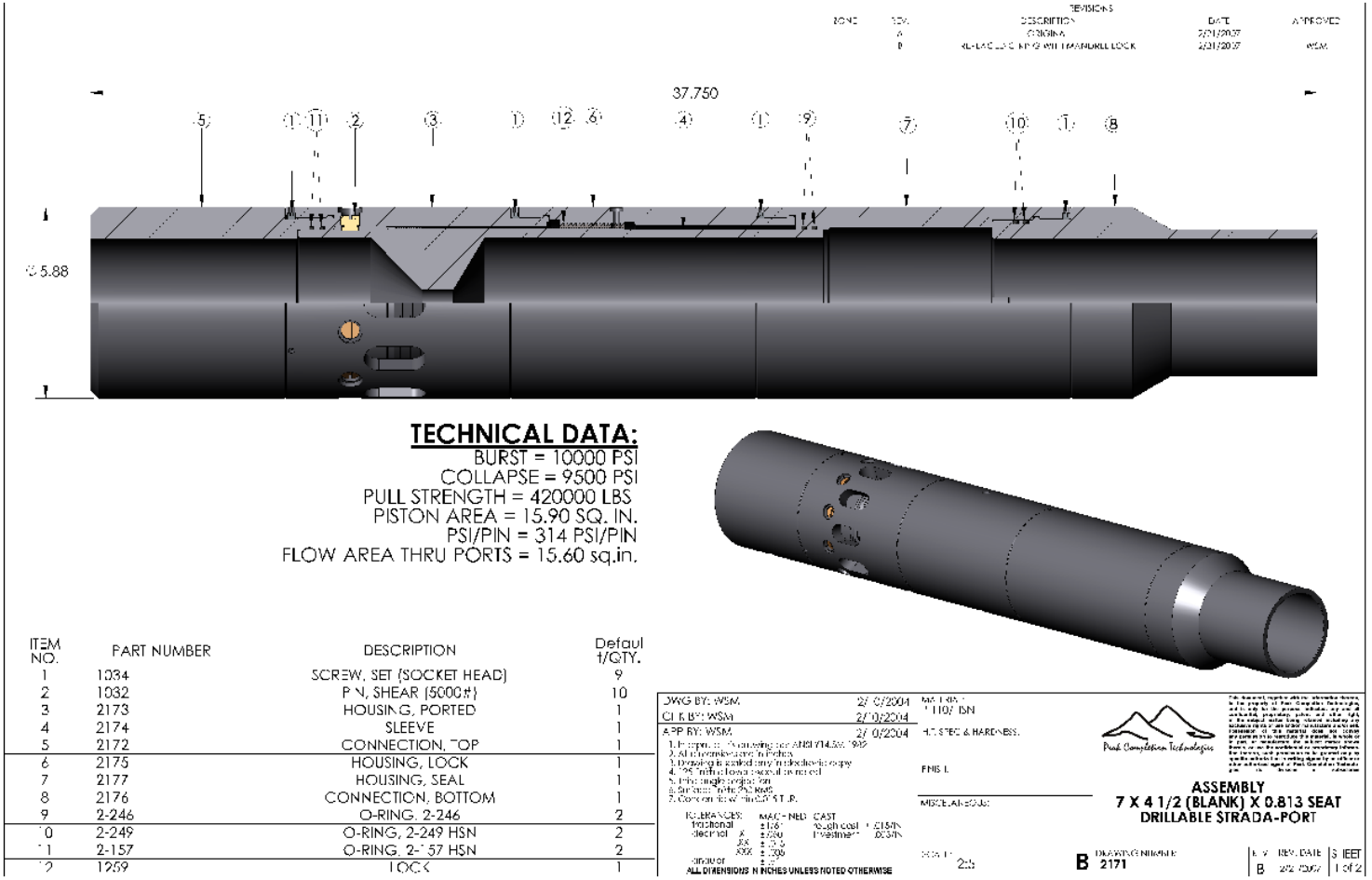
Gamma Ray Logs

- A gamma ray log is a measure of the natural radioactivity of the formations.
- The gamma ray log can be recorded in open holes and cased wells making it an ideal log for correlating.
- Nearly all gamma radiation encountered in the earth is emitted by the radioactive potassium isotope atomic weight 40 and by the radioactive elements of the uranium and thorium series.

Port and Ball Drop System with Open Hole Packers for Isolation



Ball Drop Sliding Sleeve



Thank You.

Casing Perforating Overview

Brad Hansen
Devon Energy

The statements made during the workshop do not represent the views or opinions of EPA. The claims made by participants have not been verified or endorsed by EPA.

This paper provides a general overview of casing perforating. The primary objective of a perforating gun is to provide effective flow communication between the cased wellbore and a productive reservoir. To achieve this, the perforating gun "punches" a pattern of perforation through the casing and cement sheath and into the productive formation.

In the early days (1932) perforating was performed with a bullet gun. Today the bullet gun has been almost completely replaced with the shaped-charge perforator. The shaped charge consists of a case or container, the main explosive material, and a liner.

The perforating gun consists of four components, a conveyance for the shaped charge such as a hollow carrier, the individual shaped charge, the detonator cord, and the detonator.

The three main explosives used in a shaped charge are RDX (Cyclotrimethylene Trinitramine), HMX (Cyclotetramethylene Trinitramine), and HNS (Hexanitrosilbene). The main difference between these explosives is their temperature stability. RDX is commonly used in environments less than 330 degrees F. HMX is used for temperatures up to 400 degrees F and HNS is suited for temperatures up to 520 degrees F. Each shaped charge generally contains between 3 and 60 grams of explosives.

A shaped charge perforating gun detonates almost instantaneously when the electrical charge is sent from the perforating truck. The detonation creates a jet that has a velocity of 25,000 to 30,000 ft/second. The impact pressure caused by the jet is approximately 10 to 15 million psi. This pressure overcomes the casing and formation strength and forces material radially away from the jet axis.

Most perforating guns punch holes with diameters of 0.23" to 0.72". The typical perforating guns have penetrations of 6" to 48". Most guns shoot from 4 to 12 shots per foot. Perforating guns come with different pressure and temperature ratings.

The length of the actual perforation downhole is a function of the standoff of the perforating gun from the casing. Less standoff generally means a longer perforation tunnel, while more standoff results in a shorter perforation tunnel. Phasing is the angle difference between successive perforations. Typically, perforating guns come with either 60, 90, 120, 180 or 0 degrees phasing. 60 degrees is a common phasing for a well that will be hydraulically fractured.

The API RP 19B (replacing API RP 43 in September 2006) is the recognized standard for evaluating perforator performance. However, many perforator performance tables are still published with the older API RP 43 test data given.

The two main types of carriers are the hollow carrier and the expendable shaped charge gun. The hollow carrier holds the shaped charges in a heavy wall tube that is sealed from wellbore fluids and pressure. Most of the debris from shooting this type of gun is retrieved when the gun is pulled from the well. Sometimes expendable shaped charge guns are used. This type of gun allows a larger charge to be run than a similar OD hollow carrier gun. The charge itself is sealed from the wellbore environment. Much of the debris is left in the well and falls into the rathole on vertical wells.

Wireline pressure control equipment is run above the wellhead so that the perforating gun can be run in and out of the well when the well has pressure on it. This pressure equipment is commonly known as a lubricator. Lubricators are sized by ID and working pressure. This equipment consists of a wellhead connection, the wireline blowout preventer (BOP), the riser and the control head. It may also have full opening valves, pump in subs, tool catchers and other equipment in the run. The control head is the uppermost point of the lubricator system where the wireline enters. Well pressure is controlled with packing, pack-off rubbers, grease injection or a combination of all three. The riser section is used to allow the full wireline tool string to be raised above the wellhead valve before and after the operations.

Depth control for perforating is usually accomplished with a gamma ray/casing collar locator log. Short joints are also run in the production casing to assist in the correlation. The distance from the top shot to the casing collar locator is measured before running the perforating system into the wellbore to ensure the perforations are placed where they were intended.

Gamma ray logs measure the natural radioactivity of the formations. The gamma ray log can be recorded in open holes as well as cased holes which make it an ideal log for correlating different gamma ray signatures between wells. Nearly all gamma radiation encountered in the earth is emitted by the radioactive potassium isotope (atomic weight 40) and by the radioactive elements of the uranium and thorium series.

Some horizontal completions today are completed with an openhole system below an intermediate casing string. These wells have external casing packers that form a seal between the production casing and the formation. They also have hydraulic or ball drop actuated sliding sleeves to open successive sleeves to perform multiple fracture stimulations without the need to rig up wireline and set plugs and perforate new intervals. Perforating is not required to provide effective communication between the cased borehole and the productive formation with these types of systems.