Titan SPECIALTIES, LTD.

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Electric Detonators Used in Wireline Operations

The information included in this document is intended to inform the users of Electric Detonators in Wireline Operations of their construction and function. A clear understanding of this subject hopefully will help with the determination of the various types of failures that can occur, how to diagnose and resolve them without catastrophic results.

All illustrations are generic and are not intended to represent or endorse any particular manufacturer or their product. Some of the details have been obtained from the public domain and credit for them belongs to the owner/manufacturer.

Titan does not manufacture electric detonators (with the exception of the specialized Igniters used in Setting Tool operations).

Basic Power Requirements/Specifications:

No Fire:	.2 amps	(Electric current applied to the device for I minute will not produce initiation).
Minimum Fire:	.5 amps	(Electric current applied to the device will result in a 95% probability of initiation).
All Fire:	.8 amps	(Electric current applied to the device will result in a 100% probability of initiation).
Static Sensitivity:	MIL-STD-322B	(Standard used to define the energy expressed in millijoule or mJ).

Firing current and non-resistorized vs. resistorized detonators:

Devices used in the industry today include those with a nominal circuit resistance of 1, 55, or 120 Ohms. Using these values, the specifications listed above are expressed in a usable format as:

	Voltage @ 1 Ohm	Voltage @ 55 Ohm	Voltage @ 120 Ohm
.2 amp No Fire	.2 Volts	11 Volts	24 Volts
.5 amp Minimum Fire	.5 Volts	27.5 Volts	60 Volts
.8 amp All Fire	.8 Volts	44 Volts	96 Volts

As you can see, non-resistorized detonators require a significantly lower voltage to initiate as compared to resistorized styles. Most manufacturers use "No-Fire" and "All Fire" values in their technical specifications. Graphic illustrations of the internal components and their arrangement are located in another section of this document.

Although the API RP67 specifically recommends the use of resistorized detonators, the use of non-resistorized detonators prevails today.

Static Sensitivity:

It is recognized that the human body can store a significant amount of static energy. This stored energy can cause electric detonator initiation if the energy is dissipated from an internal component of the detonator (through the lead wires) through a sensitive explosive component to the outer shell. An industry method of determining a device's sensitivity is specified in great detail in the MIL-STD-322B and the value is expressed in mJ (or millijoules). A layman's description of this can be found at the following website http://ourworld.compuserve.com/homepages/G_knott/elect63.htm. For relative comparison, a 1 ohm detonator has a value of 78 mJ compared to a 55 ohm version which has a value of 781 mJ. The most common way to bleed off the energy is through the use of a conductive rubber plug installed by the manufacturer in the end of the detonator. Bared sections of the leg wires pass through the rubber plug creating a leak path to the outer shell (see illustrations later on in this document).

Basic Construction:

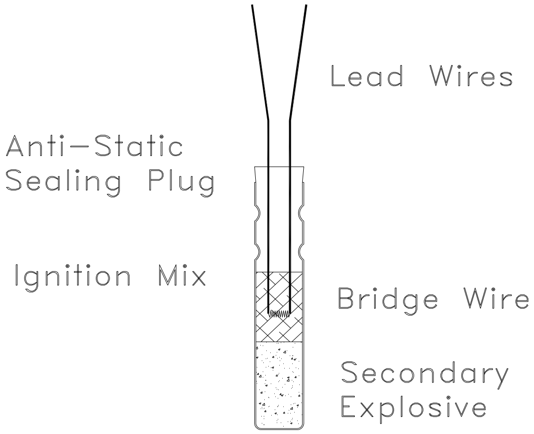

Figure 1, Non-resistorized:

The basic components of a non-resistorized electric detonator are illustrated here. This design contains a bridge wire buried in a sensitive ignition mix (typically Lead Azide) which is in intimate contact with a less sensitive secondary explosive (RDX, HMX or HNS). Primarily this design is used where fluid exposure is not anticipated.

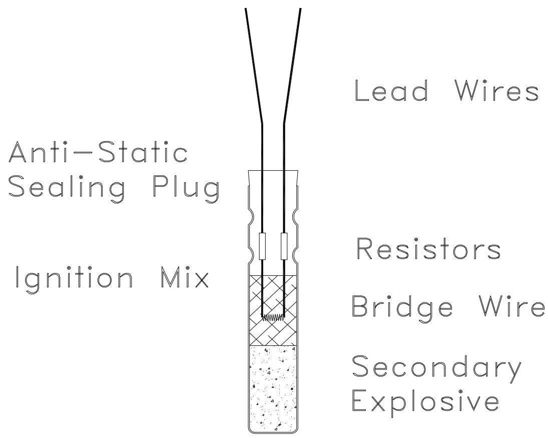

Figure 2, Resistorized

The addition of two 27 Ohm resistors (one in each leg wire) for current limitation is the primary difference between **Figure 1** and **Figure 2**. Two resistors are used to overcome space constraints.

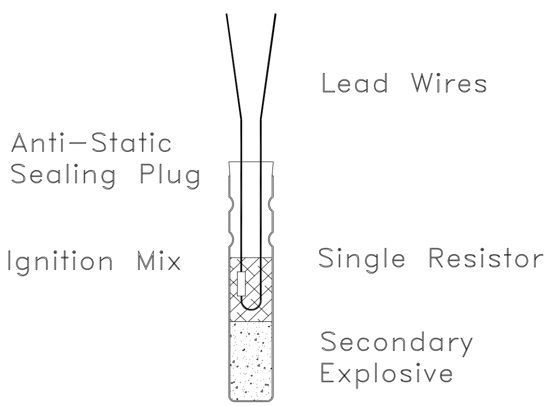

Figure 3, Resistorized

In this example a single resistor (typically 55 Ohm) is used instead of the twin resistors and bridge wire.

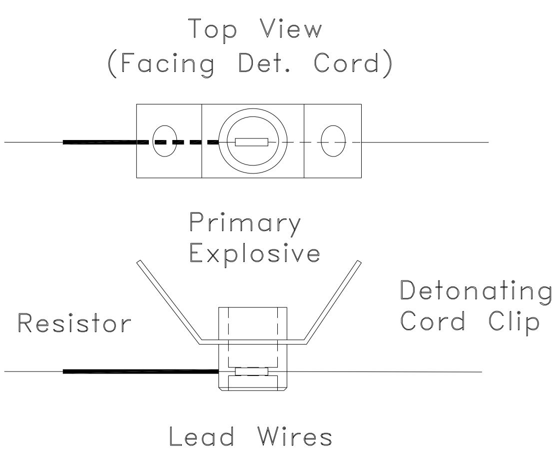

Figure 4, Resistorized, Fluid Disabled

In this example (G-21 style), a 120 Ohm resistor is in close contact with a sensitive, primary explosive (Lead Azide). One side of the lead wire is insulated and the other is not. If fluid comes in contact with the resistor it is cooled and prevented from generating enough heat to initiate the Lead Azide. The explosive is also rendered useless if the exposure is of sufficient duration.

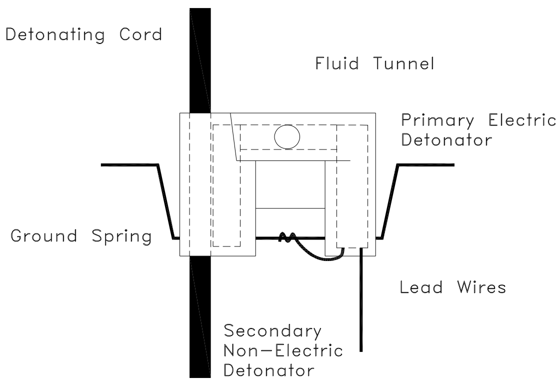

Figure 5, Resistorized, Fluid Disabled

An alternative to **Figure 4** is the "Block Detonator". It uses an Electric Detonator and a Secondary Non-Electric Detonator separated by a "Fluid Tunnel". The detonating cord is threaded through the Block adjacent to the Non-Electric Detonator as shown. Fluid (or debris) present in the "Fluid Tunnel" will attenuate the energy from the Electric Detonator, preventing initiation of the Non-Electric Detonator.

Figure 6, Alternative Design

Referring to the designs illustrated in **Figure 1, 2 and 3**, an alternative ignition system using a Fusehead (bridge wire coated with a pyrotechnic) is commonly used today. In the previous designs, to introduce fluid disabling of the device, ports are located in the chamber adjacent to the Bridge Wire. In the Fusehead style, the coated bridge wire is located in a chamber that separates it from the Ignition Mix. Ports located in the chamber area provide a path for fluid to enter into the assembly. The fluid will prevent to generation of the flame formation at the Fusehead or its projection into the ignition mix located at the other end of the chamber.

Why 55 Ohms?

Many have pondered over the reason behind the use of a 55 Ohm circuit resistance in these detonators. The original "target" for the minimum firing current was .25 amps. At that value and a circuit resistance of 55 Ohms, it required 13.75 volts or more to fire bridge wire electric detonators with this feature. This voltage level was above the commonly found 12 volt battery (and its charging system) used in and around the wellsite that was recognized as the greatest exposure hazard at the time.

Fluid Resistant vs. Pressure Resistant:

Fluid Resistant detonators usually have a low value such as 150 PSI and are used in the primary side of the Block Detonator. Because there is another mechanism to prevent the initiation of the rest of the explosive train it is not necessary to utilize a more complex device, thus lowering the cost.

Pressure Resistant detonators are constructed in such a manner to provide for the mechanical attachment of the detonating cord to the detonator while providing an environmental seal to prevent the intrusion of wellbore fluid into the assembly. Typical pressure resistance values are 10,000 – 22,000 PSI, depending on the detonating cord specifications and time exposure at pressure and temperature.

Fluid Sensitive vs. Fluid Disabled:

These terms are used to describe the relative sensitivity of the detonator when exposed to fluid. Generally speaking, Fluid Sensitive means that the device will be rendered useless after a period of time. At ambient conditions, the time exposure can be anywhere from a few seconds to several minutes, depending on the construction of the device. For instance, the example shown in **Figure 6** is designed to not function as soon as fluid enters the chamber AND wets the Fusehead. Another style of detonator not shown contains a hygroscopic shock disk that separates two components of the detonator (most commonly the Primary and Secondary Explosive). Fluid must saturate the disc to attenuate the shock wave from one component to another or wet out the Bridge Wire or Fusehead.

Fluid Disabled is usually associated with the style illustrated in **Figure 5** where the presence of fluid in the Fluid Tunnel prevents the transfer of the shock wave to the Non-Electric Detonator and is meant to be instantaneous. Because these terms can be and are used interchangeably, the user must review the technical specifications of the device he will be using and decide which one will best fit the application. For instance, if the application calls for the use of a single hollow carrier, several styles can be used. If a seal failure is experienced, the detonator should be disabled while running into the wellbore before you attempt to fire the device. If you are running a selective fire assembly and fluid enters the next gun after firing the first gun, the detonator may not have enough fluid time exposure before you attempt to fire it. The result is a ruptured gun that was partially filled when it was fired.

General Sensitivity of All Styles (containing Primary and Secondary Explosives):

If electrical energy is applied to the detonator in excess of the No-Fire level, it will fire. If it is exposed to heat beyond its maximum time/temperature rating or shock or impact energy, spontaneous detonation can occur. What you may not know are these facts:

- Pulling on the lead wires (accidentally or intentionally) can create more than enough energy to cause the ignition mix to react as if the heat was created by the Bridge Wire.
- If you are not careful of where you place the crimping tool, you could be over the top of the Lead Azide component of the detonator when you crimp the detonating cord in place. This is the MOST SENSITIVE component of any detonator assembly.
- Detonators that have been exposed to elevated wellbore temperatures should never be reused. Explosives become highly energetic (and sensitive to shock) at elevated temperatures and some of them remain that way for an extended period of time after they have been returned to ambient conditions. This can become a serious safety consideration when one or all of the conditions in first two paragraphs are encountered.
- Block style detonators (**Figure 5**) contain an electric detonator that has a low pressure rating (generally 150 PSI or less). Fluid or gas pressure can enter into the assembly and remain there until it slowly bleeds off or is caused to be released rapidly. The rapid release can be triggered by applying excessive force on the lead wires or by jarring force during the removal of the detonator from the perforating gun assembly. If the pressure is being held back by the sealing plug, it can be dislodged from the outer shell, dragging the bridge wire through the ignition mix. Several instances have been documented over the years where this has been found to be the cause of several non-fatal surface detonations.
- The cause of fluid pressure entry into the detonator is easily understood. Gas pressure entry is a bit more complicated, especially when there is none present in the well environment. Gas pressure can be generated by the explosive components being exposed to elevated temperature for a period of time in excess of their prudent time rating. This can be a result of choosing the wrong explosive for the job or pushing its operating limits. Another common source is a fluid leak into the gun. Long selective fire gun assemblies utilizing dart isolation between guns are more prone to this hazard. The dart requires a significant amount of energy (usually generated by the detonation of the shaped charges) to drive it into a seat, effectively sealing the spent gun from the next one up in the toolstring. Because, in multiple guns, the darts are not "on seat" until the gun below is fired, the annulus of the assembly from bottom to top is open. Fluid entry will compress the air column until it is equal to the wellbore pressure or it may be slow enough that the gun will be extracted before it can equalize to the wellbore. In either case, all of the components above the static fluid level in the assembly will be exposed to this compressed air column, which in turn "charge" the detonator with air pressure. As stated earlier, a sudden release of this stored energy can cause the sealing plug to dislodge, dragging the bridge wire through the ignition mix, causing detonation.

Why a Carbon Resistor?

Earlier designs incorporating a resistor(s) in conjunction with or replacing a bridge wire utilized carbon composition resistors. As you may know, when these devices are exposed to high current loads, they generate a lot of heat and when they fail, flames and smoke are the end result. In electronic components, this can also lead to collateral damage to other very expensive components. This is one of the primary reasons that the electronics industry switched to wire wound resistors (and for precise resistance values). Today, carbon resistors are commonly available in the "film" type. Instead of a cylinder of carbon with lead wires buried in each end, there is a shell of carbon surrounding an inert core attached to lead wires to provide the same resistance value as its predecessor. In comparison, a carbon film resistor is much less expensive than the cylinder style (supply and demand). Wire wound resistors cannot be reliably used for the initiation mechanism in electric detonators and the carbon film is the most cost effective and reliable.

Carbon Resistor/Bridge Wire vs. Carbon Resistor?

In earlier illustrations, it was shown that there are basically two styles of detonators that utilize a resistor(s). One where the resistor(s) is used with a bridge wire as a current limiting device **(Figure 2)** and the other where it is used by itself **(Figure 3 and 4)** to generate heat when exposed to firing voltage. The bridge wire style simply generates heat to effect initiation. On the other hand, the carbon style is quite a unique animal. One of two (or a combination of events) will occur with the application of power. In one case, the resistor overheats and ionizes, creating a white hot ember. In another, the overload causes the resistor to fragment sending hard plastic fragments into the explosive. Remember that explosives can and will react to heat and/or impact energy. The key to proper initiation is to apply power at an even, steady rate for predictable results. Many resistor/detonator failures can be attributed to the power being applied too quickly whereby the resistor fragments suddenly with little heat generated. The most common and successful firing method is to apply voltage starting at zero and increasing it to a maximum level over a period of 3 - 4 seconds. This is an easy task assigned to a computer and is commonly used in PC based logging systems. Pre-setting the firing voltage with a rheostat and "dumping" the power on the line with the firing switches will result in a high number of miss-fires. Bridge wire type detonators can be fired using this technique but the operator doesn't always know what is inside of the device. ALL detonators can be fired using the roll up technique. This is a matter of best practices, in my opinion.

One peculiar anomaly can be observed when firing a carbon resistor type detonator. The operator will notice the current and voltage meters on the firing panel respond to the power being applied as the rheostat is being rolled up. As the resistor heats up and just before the detonator fires, the current will drop off slightly. Once that event is observed, the operator usually rolls the rheostat up to full power momentarily before returning it to zero.

“Safe” Detonators

High Energy Style detonators are newer class of devices intended to enhance the safety of operations using ballistic devices, primarily in unknown RF frequency and strength environments. The one thing that all of these devices have in common is that they contain no sensitive, primary explosives such as Lead Azide. These devices are usually referred to as (and a brief description of their attributes):

- EBW or Exploding Bridge Wire – The traditional Bridge wire is replaced with a robust material bridging two internal contacts. A firing cartridge stores energy (voltage applied from the firing panel) until it reaches a pre-determined level and is discharged across the bridge wire. The energy is dissipated in a manner that causes the wire to explode thus transferring the energy to the secondary explosive with enough energy to initiate it.
- EFI or Exploding Foil Initiator – Very similar to the EBW except that a foil disk is propelled into a target of secondary explosive with sufficient energy to initiate it. Also referred to as a “Slapper Device”.
- SCB or Semi Conductor Bridge – Similar to EBW whereby a large energy source is dumped across an electronic device causing it to catastrophically fail and the resulting energy is directed into the secondary explosive. This is the device that deploys the airbag in your vehicle.

All of these devices require the application of voltage stored in a discharge device until the voltage level reaches level (some up to 1,200 volts) that will cause the violent destruction of some component to release the energy into the explosive. They all have their drawbacks. Firing leads must be kept short, they will not tolerate any insulator leakage between the storage/discharge unit and the detonator or arcing will occur.

Some devices require a non-standard AC frequency (600 Hz) or can also be integrated with a digital signature code to effect firing.

Google (on the Internet) semiconductor bridge, exploding foil initiator, Rig Environment Detonator and PX-1 fireset for additional information. Also search all of the known manufacturers websites for proprietary “Safe” initiation systems, panels and detonators. There is a lot of interesting data out there.

I hope this information proves to be useful and stimulates the curiosity to learn more.

In the past 30 years I have investigated many accidents, injuries and deaths associated with surface detonations. The vast majority have been due to the accidental application of firing power from the surface by a human. Even the “safest“system is susceptible to this event. We must continue to train and raise the awareness of all individuals associated with operations involving explosives to be diligent regarding their responsibilities to themselves and others.