



A Technical Description of the Rig Environment Detonator (RED[®])

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1.0 User Responsibility

This document describes a detonator product line designated the Rig Environment Detonator (RED). It represents a type of electroexplosive device that exhibits greater safety characteristics than conventional hot-wire or resistorized detonators. Nevertheless, they are detonating devices and by their very nature are designed to explode. Hence they must only be used by personnel properly trained in their use and familiar with the safe handling of explosives.

The RED devices are manufactured under strict quality control and their designs have passed rigorous qualification tests summarized in this document. These tests show the RED to be insensitive to certain levels of hazards; however the RED can still function if these hazard levels are exceeded, or if the device is improperly applied either by unintentional misuse, carelessness, or negligence. Accordingly it is the responsibility of the user to verify that these hazard levels are not exceeded when the RED is being used, and that RED devices are handled only by personnel that have been properly trained.

Users of the RED product line should always refer to their respective company's safety policies and procedures with respect to the use of electronic and/or RF devices in the vicinity of explosives or detonators.

Required Notification Information: The information found within this document shall not be construed as recommendations for service companies other than Halliburton or detonating systems other than the RED detonator product line.

2.0 Introduction

The Rig Environment Detonator (RED[®]) is a specially designed electro-explosive device that allows safer wellsite explosive operations to be conducted. The RED possesses two major safety advantages over resistorized detonators used in the oilfield:

1. No primary explosives, such as lead azide, are utilized in its construction. Instead the design is based on a deflagration-to-detonation technique utilizing an insensitive pyrotechnic and secondary explosives. A semiconductor bridge (SCB) element, similar to those used in automotive airbag systems is used to initiate the deflagration reaction.
2. It is insensitive to many common electrical hazards encountered around wellsites. This is accomplished by the combination of the 5-watt no-fire level of the SCB and the incorporation of an internal protection/firing circuit which is similar to those used in exploding bridgewire (EBW) and exploding foil (EFI) systems. The circuit however operates at lower voltages than those required by EBW and EFI detonators and can thereby be functioned using standard wireline firing panels.

During the RED development history, it was subjected to RF hazard tests at various testing agencies and laboratories located in the United States including DNB Engineering, Franklin Applied Physics, and Sandia National Laboratories. A fourth testing laboratory in the United Kingdom, ERA Technology Limited, also evaluated the RED and reported it to be safe from RF hazards on North Sea oil production platforms.

The Rig Environment Detonator has also passed other hazard tests including electrostatic discharge, stray voltage, and impact. The levels of hazards passed by the RED in these tests always met or exceeded those of resistorized detonators.

The Rig Environment Detonator is available in four configurations that cover virtually any oilfield perforating situation or explosive operation. Firing is accomplished by application of 150 – 190 volts DC to the device. This firing energy is usually supplied from standard wireline surface firing panels or can be supplied from appropriate electronic trigger devices that are used in certain slickline operations.

3.0 Principles of Functioning

Figure 1 shows a schematic of the RED and its protection/firing circuit. Firing is accomplished by applying DC voltage across the detonator leads which causes a firing capacitor to charge until a fixed voltage gap breaks down between 150 – 190 volts DC. Upon discharge, current flows rapidly through the semiconductor

bridge causing it to vaporize. The extremely hot plasma gases generated by bridge vaporization (around 5500 deg Kelvin) cause the insensitive pyrotechnic to ignite. This in turn starts a deflagrating reaction to begin in the adjacent secondary explosive column. The deflagration proceeds down the column and subsequently transitions to a detonation as a result of special design considerations within the RED. The detonation output is then coupled to other explosive components in the train to complete the explosive sequence (boosters, detonation cord, or power charges for example). In the event of a downhole misrun, a bleeder resistor in the circuit discharges the capacitor and thus disarms the device. Disarm time is on the order of 5 seconds.

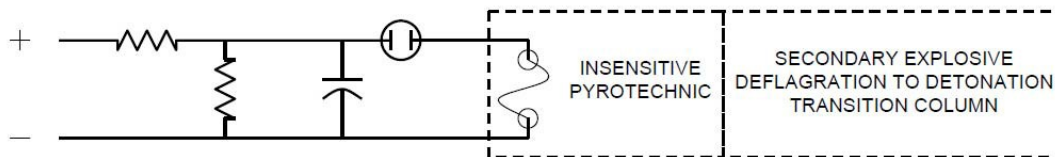


Figure 1.

Since the RED is a voltage-initiated device it is ideally suited for situations involving high resistance wireline cables, such as those constructed from MP-35N. These types of cables do not readily permit current flow and thus often present operational problems when using current-initiated devices such as resistorized detonators. The RED avoids this problem completely due to its principle of operation.

4.0 RF Hazard Tests

Radio frequency hazard tests on the RED were conducted by different independent laboratories such as Franklin Applied Physics and Sandia National Laboratories during its development history. During these test programs direct radio frequency energy was injected into RED devices at frequencies ranging between 1.5 and 8,900 MHz. Power levels were at least 5 watts for 5 minutes, but in many cases much higher (up to 25 watts for 5 minutes). In all instances none of the devices fired when subjected to direct RF injection.

A different testing agency, ERA Technology Limited, used data generated by Franklin Applied Physics to perform an RF hazard assessment on the RED. They concluded that no RF hazards exist to the RED when used in the electromagnetic environment of a North Sea oil production platform.

A fourth testing laboratory, DNB Engineering Inc., conducted radiated susceptibility tests under MIL-STD-461D at frequencies from 260 kHz to 18 GHz and corresponding field strengths up to 300 V/m depending on frequency. Tests were conducted with the radiating antenna in vertical and horizontal polarizations

at a distance of one (1) meter from the RED. There were no resulting detonations from the devices under test.

Excerpts from test reports generated by these organizations are given below.

From Franklin Applied Physics:

The Halliburton SCB detonator uses a modified coaxial configuration – much to be desired for electromagnetic safety...

...the device incorporates a firing capacitor, a spark gap and a semiconductor bridge element – all of which can be conducive to decreased high frequency electromagnetic sensitivity.

The data obtained indicate that the Halliburton SCB detonator will not initiate with five watts applied to it for five minutes at any of the test frequencies.

Because the device is so insensitive, it was not practical to statistically determine the actual no-fire level, however, at least one detonator withstood more than five watts at each frequency.

We believe that the Halliburton SCB detonator is the most insensitive electro-explosive device that we have ever tested in this manner.

From Sandia National Laboratories:

Due to the design of this circuit, the capacitor will act as a short to the RF energy at low frequencies (10 MHz – 300 MHz). Frequencies above the low range (300 MHz – 1 GHz) will be stopped by the gap switch.

The SCB showed no physical damage for any of the tests as determined by resistance checks and examination of the bridge under a microscope.

From ERA Technology:

No hazard exists to the RED from typical measured or calculated ambient electric field strengths on North Sea Oil production platforms.

In addition, SCB Technologies, Incorporated, through whom the Sandia tests were conducted, commented on the Sandia test results:

...it is next to impossible to get any energy into the SCB when it is in your [RED] device. It is better protected than any protection scheme that I have seen.

You certainly have an excellent device.

From DNB Engineering:

The EUT [Equipment Under Test] showed no signs of degradation during the performance of this test.

5.0 Electrostatic Discharge (ESD) Tests

The Rig Environment Detonator was subjected to electrostatic discharge tests at Franklin Applied Physics. The test method generally followed MIL-STD-1516, Method 2205, except that the SCB detonator did not have a pins-to-case mode because of the favorable coaxial configuration so the test was conducted in the pin-to-pin mode. This MIL-standard is intended to simulate a worst-case human body static discharge by using a 500 pF capacitor at 25 kV discharging through a 5,000 ohm resistor in series. When subjected to this test none of the detonators fired, thus confirming the RED's insensitivity to human body electrostatic discharge.

6.0 Impact Tests

Impact tests were conducted on the RED by dropping a 13 lbm (5.9 kg) cylindrical steel weight from a height of 90 inches (228 cm) onto test specimens. The face diameter of the weight was 1.38 in (34.9 mm) and the RED was positioned on a 0.5 in (12.7 mm) thick steel plate supported by a concrete base. The RED was thermally conditioned to 375°F (190°C) for one hour in order for the HMX to undergo a phase transformation to the more sensitive δ -polymorph. Even under these conditions no impact reactions occurred; only the housing flattened by approximately 25%. Heights greater than 90 inches were not possible in the test series due to limitations of the test apparatus.

By contrast, conventional detonators in thin-wall aluminum shells containing primary explosives exploded when impacted by the same weight from a height of 57 in (145 cm).

7.0 Stray Voltage and Welding Tests

The circuit design of the RED allows it to withstand DC voltage levels to a minimum of 120 volts. This makes it insensitive to stray voltage hazards such as those arising from 12- and 24-volt batteries and cathodic protection systems (generally operating around 50 volts). This was demonstrated by applying 120 volts DC to the RED for 5 minutes with no resulting initiations.

The RED is also able to block welding voltages, since a typical open circuit voltage for a welding machine is around 80 volts. To determine this capability, a test was conducted using three detonator types:

1. A conventional one-ohm blasting cap
2. A 55 ohm resistorized detonator
3. A RED

To conduct a test a detonator was placed in the welding loop such that the detonator was directly a part of the circuit, such that the ground leg of the detonator was connected to the ground lead of the welder and the positive leg was attached to a steel plate. The welding machine's electrode was then struck on the steel plate, completing the circuit. Both the one-ohm and 55 ohm detonators fired immediately. The RED did not fire with repeated strikes of the electrode. The RED was subsequently removed from the circuit and fired in the proper manner using a standard surface firing panel.

8.0 THKP/HMX Compatibility Tests

The Rig Environment Detonator uses THKP, an insensitive pyrotechnic, and HMX, a secondary explosive, in its construction. These materials are used in contact with each other, and to assure their compatibility at elevated temperature, differential scanning calorimetry and adiabatic reaction calorimetry tests were run at Sandia National Laboratories. Their results show that THKP and HMX are chemically compatible and thus can be used in contact with each other.

9.0 Available Configurations

The RED family consists of four styles:

Block RED

The Block RED is used with bottom fired hollow carrier perforating guns and with select-fire guns. It is rated to 375°F for one hour and is designed to be used with 80 grain/ft RDX and HMX detonating cords.

Lead lengths of the detonator are 12 inches; the red wire is positive and the black wire negative (ground). It is recommended that an arming sub be used with the Block RED to facilitate loading.

Top Fire RED

The Top Fire RED is used with tubing and casing cutters as well as top-fired hollow carrier perforating guns. Special adapter subs also allow the Top Fire RED to be used with exposed explosive systems such as capsule guns or string shots. The detonator is rated for 375°F for one hour. The contact spring at the top of the detonator is the positive lead while the barrel spring on the outside of the housing is negative (ground).

Capsule RED

The Capsule RED is a high pressure detonator used in exposed downhole applications such as with capsule guns or string shots. The central hermetic pin is positive and the housing is negative (ground).

The detonator itself is rated to 375°F at 15,000 PSI for one hour, but to realize the full rating the proper detonating cord must be used. Table 1 shows the types of detonating cords that have successfully passed testing in fresh water with this style of detonator. Other detonating cords may work at different conditions, but it is the responsibility of the user to verify their suitability. The user is also cautioned that detonating cord thermal and chemical resistance may vary among the cord manufacturers, so it is always recommended to conduct appropriate qualification tests with the Capsule RED to verify proper functioning at downhole conditions.

Description	Maximum Recommended Temperature (°F)	Maximum Recommended Pressure (PSI)
RDX: Std Velocity, Low Shrink, Plastic Jacket 80 gr/ft	300	15,000
HMX: XHV, Low Shrink, Plastic Jacket 80 gr/ft	350	15,000
HMX: Lead Jacket 87 gr/ft	350	15,000
HNS: Lead Jacket 87 gr/ft	375	15,000

Table 1. Representative Temperature and Pressure Ratings for Capsule RED

Thermal Igniter RED

The Thermal Igniter RED is used to initiate power charges and other pyrotechnic tools such as cutting torches that require a hot flame output for initiation. It is rated to 375°F for one hour.

The contact spring at the top of the detonator is the positive lead while the barrel spring on the outside of the housing is negative (ground).

10.0 Recommended Arming and Firing Procedure

All versions of the RED should be armed following the basic safety philosophy described in API RP-67. This requires that the detonator must be placed into a safety tube before attachment to the shooting line and the proper arming sequence adhered to: electrical coupling to the wire-line first, followed by ballistic attachment to the explosive train. All versions of the RED are amenable to arming electrically before ballistically, and it is the responsibility of the user to make certain this procedure is followed. It is important to ensure that proper grounding between the safety tube and perforating gun be maintained during electrical arming so that the safety tube and perforating gun are always at the same electrical potential.

To fire the RED using surface wireline shooting panels, the dump fire method is recommended. This is best accomplished by the following:

- Preset the shooting panel voltage knob to deliver 250 VDC positive or negative at the firing head.
- Mark the shooting panel at the 250 VDC position; return to the zero position.
- When ready to fire the device, turn the knob to the mark on the shooting panel and engage the firing switches to dump fire.
- Increase voltage to a higher level if necessary to fire the detonator and/or switch the shooting polarity if necessary.

OTHER FIRING METHODS MAY BE EMPLOYED BUT OFFER RISK OF MISFIRE.

For electronic triggering devices that are not able to deliver 250 VDC over a three second period of time, there are specialized versions of the Top Fire and Thermal Igniter REDs which are screened to fire between 150 – 170 VDC rather than 150 – 190 VDC. These screened REDs can be useful for slickline applications where firing power from an electronic triggering device is less than 250 VDC.

11.0 Shipping Information

Block REDs are approved for transportation in accordance with the following information:

Proper Shipping Name: Detonators, Electric
UN Number: UN0255
DOT Classification: 1.4B
EX Number: EX1995010044
Product Designation: HES-APRV-003, *Electric Detonator Family*

The Top Fire, Thermal Igniter, and Capsule versions of RED are approved for transportation in accordance with the following information:

Proper Shipping Name: Detonators, Electric
UN Number: UN0255
DOT Classification: 1.4B
EX Number: EX1995010044
Product Designation: HES-APRV-003, *Electric Detonator Family*

12.0 Summary

A family of detonating devices exhibiting greater safety than resistorized detonators has been described. These new devices do not contain primary explosives and offer increased protection from stray voltage and RF hazards normally encountered around land and offshore wellsites. Recognized testing laboratories in both the United States and United Kingdom have attested to the improved safety of these devices.

As a result, when using RED devices it is permissible under API RP-67, Section 2.6.2.6 to waive certain field safety procedures described in that document, specifically:

Stray Voltages

The RED product line can be used in environments with stray voltage conditions of up to 2 V. For stray voltages higher than 2 V, electro-explosive operations are not allowed due to personnel safety issues, not explosive issues. Levels of voltage above 2 V indicate a serious problem on the wellsite that may directly affect personnel through other hazards such as electrical shock.

Cathodic Systems and Electric Welding

For environments where impressed cathodic protection and welding operations are present and functioning properly (ie, stray voltage levels are less than 2 V),

the RED can still be used since the no-fire voltage is confirmed by testing each device during manufacture to be above 120 VDC. This level is significantly higher than the open circuit voltages for either cathodic systems or welding, which prevents a power spike from the wellsite operations under fault conditions from inadvertently initiating a RED device.

Radio Frequency Energy

Perforating operations can be conducted without interrupting radio communications.

While independent test results show the RED product family can withstand high levels of radio frequency (RF) energy at less than one (1) meter without functioning, it is not good explosive practice and likely unsafe to allow any electrical device having an onboard power supply such as batteries to come closer than one (1) meter to any electrical detonating device.