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SAFETY GUIDE FOR THE PREVENTION OF RADIO FREQUENCY RADIATION HAZARDS IN THE USE OF COMMERCIAL ELECTRIC DETONATORS (BLASTING CAPS)

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Federation of European Explosives Manufacturers
Brussels, Belgium

institute of makers of explosives

1120 NINETEENTH STREET, N.W.
SUITE 310
WASHINGTON, DC 20036-3605
(202) 429-9280
www.ime.org
info@ime.org

The Institute of Makers of Explosives (IME) is the safety & security association of the commercial explosives industry in the United States and Canada. The primary concern of IME is the safety and security of employees, users, the public, and environment in the manufacture, transportation, storage, handling, use, and disposal of explosive materials used in blasting and other essential operations.

Founded in 1913, IME was created to provide technically accurate information and recommendations concerning commercial explosive materials and to serve as a source of reliable data about their use. Committees of qualified representatives from IME member companies developed this information and a significant portion of their recommendations are embodied in regulations of state and federal agencies.

The Institute's principal committees are: Environmental Affairs; Legal Affairs; Safety and Health; Security; Technical; and Transportation and Distribution.

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FOREWORD

Those who manufacture and market commercial explosive materials have an absorbed and active commitment to the safety of their employees, the users of the products, the environment, and most important of all, the general public. Because commercial explosive materials and explosive devices are not ordinary commodities, but specialized and inherently dangerous products, companies making them have devoted substantial attention to safety and security in the commerce of these products. When the safety record of the explosives industry is examined, it becomes clear that their efforts have been effective.

One reason for this excellent performance has been the adoption of and the adherence to safety standards and procedures by the member companies of the cognizant manufacturer's association, the Institute of Makers of Explosives.

Recently the marked increase in the proliferation of RF sources, particularly portable sources such as mobile radio transmitters, wireless asset tracking systems, and cellular telephone systems, has placed added focus on the need for re-examination of the safety issues associated with electrically-initiated blasting operations in the vicinity of fixed and mobile RF sources. The function of this pamphlet is to suggest guidelines for the safe use of commercial electric detonators in locations near to RF energy sources. Safety Library Publication 20 was recently expanded to include safe distance tables from radio frequency sources pertaining to 50 ohm resistorized electric detonators commonly used in oilwell perforating or other wellsite services using explosive devices. However, this pamphlet does not apply to other sources of electrostatic or electromagnetic energy such as atmospheric electrostatic charge, lightning or power transmission systems.

DISCLAIMER

The guidelines in this pamphlet are intended to provide a basis for assessing the hazards associated with conducting blasting operations utilizing commercial one ohm conventional electric detonators or 50 ohm oilfield electric detonators in the presence of radio frequency (RF) energy fields by indicating recommended safe distances from non-military RF sources. The recommendations presented herein were based on analysis and research of the RF sensitivity of commercial electric detonators for which “no-fire” current levels and RF sensitivity were established. For information on a specific commercial electric detonator being used, it is suggested that the user of the device contact the manufacturer to obtain “no-fire” current data and test results of RF sensitivity tests. The following tables do not apply to military electro-explosive devices such as detonators, igniters, or other electro-pyrotechnic devices such as those devices used in weapons systems, propulsion systems or other military related applications.

It is not possible that every configuration of blasting circuit and RF source could be covered in this pamphlet, particularly in the case where multiple RF sources of different frequencies and RF field intensities are present. If there is any doubt as to conducting electrically initiated blasting operations in a location where RF field intensity is a concern, it is recommended that competent expert advice be obtained, RF field intensity measurements be made and, if necessary, means of shot initiation employed which are relatively insensitive to RF energy.

It is also important to note that the recommendations presented in this pamphlet, as with all of the other IME Safety Library Publications, are subject to revision as new technology is developed in the industry, the blaster’s working environment changes or new regulations are imposed. It is the responsibility of the persons using explosive products to ensure that the most recent issues of the safety library publications are used for reference. It is necessary to check for revisions to the SLPs periodically. The IME may be contacted through the address, telephone number or fax (shown in Table 15), or e-mail at info@ime.org.

PURPOSE AND SCOPE

This guide is intended to provide a basis for assessing the hazards associated with initiation of commercial electric detonators by radio frequency (RF) energy by indicating safe distances from commercial RF sources.

Part I presents basic information of the mechanism of RF initiation and its avoidance.

Part II presents tables of safe distances from RF sources for conventional one ohm electric detonators developed by analytical calculations and supported by many field tests. Adherence to these tables will give the blaster a high degree of assurance that his blasting layout will be safe against RF initiation.

Part III presents tables of safe distances from RF sources that apply to 50 ohm resistorized oilfield electric detonators. These tables are based on test data obtained from testing samples of oilfield electric detonators at an independent test laboratory and establishing a "worst case no-fire" power level that applies to this type of electro-explosive device.

Part IV presents data on some common sources of radio frequency emissions.

The statements in this booklet apply solely to commercial electric detonators that have been characterized by a credible test laboratory. They do not apply to military, or other specialized, electric firing devices. They are based on competent analysis and research and are believed to be accurate. However, no guarantee of their applicability is made because we cannot cover every possible application nor anticipate every variation encountered in the use of electric detonators.

Occasionally, situations develop where adherence to the tables of safe distances as stipulated in this booklet becomes an operational handicap. Or situations develop which are so unusual as not to be covered in this booklet. In these instances, we recommend that competent experts be consulted to evaluate your particular situation. These experts will have the ability to make field measurements at the blasting site so that the RF hazard can be evaluated.

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PART I

A. Introduction

Radio-Frequency (RF) transmitters, which include (among other types of service) AM and FM radio, television, radar, cellular phones, wireless data acquisition systems, Global Positioning System (GPS) base stations, and radio navigational beacons, etc. create powerful electromagnetic fields, decreasing in intensity with distance from the transmitter antenna. Tests have demonstrated that electric detonator wires, under certain circumstances, may pick up enough electric energy from such fields to cause the detonators to explode.

A need was recognized to revise this pamphlet as a direct result of recent changes to the RF spectrum and a substantial increase in the numbers of portable RF emitters and communications services. As with the previous versions of this pamphlet, this version applies only to commercial electric detonators. The pamphlet does not apply to electronic detonators with protective circuits, exploding bridge wire detonators, exploding foil initiators, or detonators designed for use in RF environments. Users of such devices should consult with the manufacturer of the device to determine the RF environment for which the device is safe for use, the proper firing system for reliable initiation and any restriction on firing circuit configuration or length.

B. Magnitude of the RF Energy Hazard

From a practical standpoint, the possibility of a premature explosion of electrical detonators due to RF energy is extremely remote.

The estimated annual consumption of electric detonators in North America is in the tens of millions. They are used in every region of the continent. To date there have been a few authenticated cases of a detonator being fired accidentally by RF pickup. Investigation showed that if the recommended separations had been adhered to, even these events would not have happened. This long-term experience and also numerous tests indicate that if proper precautions are taken, such as adherence to the enclosed table of distances, the probability of an accidental firing from RF energy is practically nil.

C. RF Initiation

The usual method for firing an electric detonator is to apply electric energy from a blasting machine, power line or other source of electric power to the firing line connected to the electric detonator. Electric current flows through the wires to the detonator and a small resistance wire inside the detonator heats a surrounding pyrotechnic material to its ignition temperature.

If the electric detonator wires are in a strong RF field (near a transmitter that is radiating RF power), the unshielded leg wires or circuit wires, whether connected to a blasting machine or not, or shunted (short-circuited ends) or not shunted (open ends), will act as an antenna similar to that on a radio or TV receiver. The RF field will induce an electric current in the circuit wiring which will flow through the electric detonator connected to it.

In certain cases, depending on the strength of the RF field and the antenna configuration formed by the detonator wires and its orientation, sufficient RF energy may be induced in the wires to fire the electric detonator.

D. RF Sources Presenting Hazards to Blasting Operations

1. Blasting Operations on the Surface

Commercial AM broadcast transmitters (0.535 to 1.605 MHz*) are potentially the most hazardous. This is because they combine high power and low enough frequency so that there is little loss of RF energy in the lead wires.

Frequency-modulated FM and TV transmitters are unlikely to create a hazardous situation. Although their power is extremely high and antennas are horizontally polarized, the high-frequency currents are rapidly attenuated in detonators or lead wires. These RF sources usually employ antennas on top of high towers. This has an additional effect of reducing the electro-magnetic field at ground level.

Mobile radio, as well as other wireless products, must be rated as a potential hazard because, although their power is low, they can be brought directly into a blasting area. New wireless products, such as cellular phones, Global Positioning Systems, data acquisition systems, and remote vehicle entry systems, are continually being brought to market.

Citizens Band (CB) radios are an unusual problem for several reasons: 1) there are millions of units being used by the general public; 2) their operating frequency is in range that is considered to be worst-case for typical electric blasting circuits and 3) some irresponsible operators use illegal linear amplifiers to increase their transmission range. Safe distances are recommended for the FCC approved, double sideband (4 watts maximum output power) and single sideband (12 watts peak envelope power) units in Table 3. It is not possible to specify safe distances for the illegal units because they do not operate within established FCC limits that can be used for making definitive worst-case assumptions.

The U.S. Department of Transportation, Federal Highway Administration, Manual on Uniform Traffic Control Devices (MUTCD), December 2009 requires the posting of signs within 1,000 ft. of construction sites warning that two-way radios and cell phones should be turned off because of blasting. Observance of the posted signs will provide the necessary degree of safety if the units are a maximum of 200 watts peak power. It is recommended, therefore, that all CB operators, users of mobile transceivers and cellular telephones obey posted signs and turn off their units in observance of posted warnings or if they know that there are blasting operations in the area.

Two way radios and wireless data transmission and control radios are routinely used in surface mining and blasting operations. When radios are used for this purpose, the minimum separations specified in Table 3, for a particular transceiver (frequency and power) should be maintained.

There is little possibility that sources of RF energy such as microwave relay will ever constitute a practical problem. They are all characterized by one or more of the following: (1) location in areas where blasting is unlikely, (2) ultra high frequency, and (3) restricted radiation patterns. However, particular attention should be paid to all directional RF sources such as fixed and mobile marine radar. Directional RF sources such as radar use specialized antennas that concentrate the transmitter power in primarily one direction. Such high gain antennas significantly increase the effective radiated power of the transmitter. In the vicinity of high power radar installations, blasting should not be conducted.

*MHz – Megahertz = 1,000,000 cycles per second.

2. Blasting Operations Underground

In the case of underground mining, only MSHA approved tracking and communication equipment should be used and then only within the restrictions or limitations specified in the MSHA approval.

Radio-frequency transmitters used in underground mining operations could present a hazardous situation. As a result of several recent serious incidents in underground mining, the Mine Improvement and New Emergency Response Act of 2006, (MINER Act), was enacted requiring the adoption of miner communication and tracking systems for improving the safety of underground miners. The act contains two parts, the first requiring an emergency response plan providing for redundant means of communication between the underground miners and the surface enabling personnel on the surface to determine the location of miners underground prior to and immediately following an incident. The second part requiring a means of communication with miners trapped underground following an incident. The communications and tracking, (CT), systems encompass a number of different technologies operating in an environment much different than the free field electromagnetic environment on the surface.

Systems for tracking and communication in underground mines may be wired or wireless, technically however, there is a considerable grey area between the two. For example, a two-way walkie-talkie pair is purely a wireless communication system, whereas, a cellular telephone system is not. The wireless links in a cellular telephone system are the system segments between the personal communication devices and the cellular towers. The cellular towers communicate to a landline telephone system. The manner in which the MINER Act's requirements could be interpreted is that the miners themselves are to be un-connected by hardwires to a communication system, and the communication system must be survivable.

Wired systems in mines may be local landline telephone systems or trolley telephones where rail systems exist. Neither is particularly robust in the event of a rockfall, roof collapse, or other disturbance.

Wireless systems consist of discrete and distributed antenna systems, leaky feeder systems, and nodal-type wireless systems. A major concern insofar as the use of wireless communication and tracking systems is the possible problems with their close proximity to electric detonators and electrically-initiated blasting circuits using conventional hot-wire detonators. MSHA should be contacted to determine if a particular system is approved for use in underground mines and any limitations that may be imposed on its use.

In the case where low frequency or medium frequency systems are used, (10 MHz or less), in underground mining, a dominant form of coupling between the electromagnetic source and the electric detonator and/or its associated wiring is by magnetic coupling in the immediate vicinity or near field of the electromagnetic current source and its current-carrying conductors. Blasting wiring should be kept well away from trackage and trolley phone systems. Since physical conditions in the drift vary and communication systems vary in characteristics and configuration, it is prudent to have a qualified independent test laboratory survey the installation and establish safe distance requirements. This particularly applies to metal/non-metal mines as well as underground coal as the presence of nearby metallic objects or metallic ore bodies may have a pronounced effect on the electromagnetic fields. Although researchers try to establish "worst case" scenarios for establishing safe operating distances between RF or electromagnetic sources and electric detonators and their associated wiring, it is never prudent to attempt to use guidelines on safe distances where they do not apply

Because of the uncertainties of RF absorption and scattering within mine tunnels, the potential hazard can only be evaluated with the aid of consultants.

In the case of underground mining operations, it is also suggested to refer to the United States Department of the Interior, Bureau of Mines Report Investigations RI 9479, "Effect of Ultralow Frequency Signaling on Blasting Array Current", dated 1993 for information on electromagnetic fire warning systems and blasting circuit safety.

3. General Precautions concerning electrically-initiated blasting and RF

It must be noted that not all antenna systems radiate RF energy at equal intensity in all directions. For certain broadcasting operations, a broadcaster may wish to target a particular audience for its transmission and the antenna is configured to radiate at maximum intensity in preferred directions. Or low power transmitters, to make maximum effective use of their permitted transmitter power, may use highly directional antennas to radiate in certain preferential directions. A directional antenna is characterized by a gain larger than one, thus the maximum effective radiated power of the antenna is the power input to the antenna multiplied by the antenna gain. Some cases where directional antennas are frequently encountered are noted in Tables, 4, 5, 6, and 7 and the power levels in the tables are listed as maximum effective radiated power.

E. Cellular Telephones

The rapid growth in the use of cellular telephones and cellular telephone service installations has raised concern in the explosives industry over the safety of such personal communications devices and installations operating in the vicinity of electric blasting circuits. The following should assist in providing guidelines for the safety of electrically-initiated blasting operations and these devices.

1. Cellular Telephone Service Towers

In 1981, the United States Federal Communications Commission adopted rules creating a commercial cellular radio telephone service. In the U.S., four sections of the 800-900 MHz UHF frequency bands are designated for the service's operations, 824-849 MHz, 869-894 MHz, 896-901 MHz, and 935-940 MHz. A cellular system operates by dividing a geographical region into cells. As a subscriber to the service travels through the area, a call is transferred from one cell to another without interruption except perhaps by local terrain features. All of the cells are connected to a switching center by landline or microwave service to link the call to a public wireline telephone service. Therefore, this system requires the construction and operation of a series of UHF wireless towers to support the service. In the United States, the Telecommunications Act of 1996 specifically leaves in place the authority that local zoning boards have over the placement of cellular telephone facilities.

It may be quite possible that such towers are located in the vicinity of fixed blasting locations such as mines or quarries or locations of temporary blasting operations such as construction or demolition sites.

Generally the average cellular telephone service tower height is 110 to 120 feet and operates with a maximum effective radiated power of 500 watts, however, the radiated power in any one direction would rarely exceed 50 watts.

If a 500 watt assumption is used for the estimated output of the tower, the resultant safe distance to blasting circuits should be adequate as the rolloff of the antenna RF output with vertical angle between the radiator and the ground is very sharp. It must be noted that some antenna towers are difficult to identify as they may be concealed to blend into their surroundings for aesthetic reasons.

If it is suspected that the blasting circuit would be located at approximately the same elevation as the tower's antenna cluster then RF field strength measurements should be made at the location of the blasting circuit and competent expert advice sought.

2. Cellular Telephones

Although the hand-held battery-powered cellular telephone is, by design, a low-power device, operating at 0.6 watt or 3.0 watt, to keep the specific absorption rate, (SAR), below recommended safe levels for human tissue, there are concerns with the use of cellular telephones in the vicinity of blasting circuits.

First, due to the portability of the cellular telephone, the device can be brought into very close proximity or contact with a blasting circuit. An antenna of a cellular phone could be damaged allowing the bare metal antenna mast to contact the leg wires of a detonator or the blasting circuit leads. Cellular telephone handsets with output of 3 watts or less should be kept 13 feet from blasting circuits. Cellular telephone handsets with an output of 0.6 watts should be kept 8 feet from blasting circuits.

Second, the battery charging jack or charging points of a cellular telephone could also come into contact with a detonator's leg wires or the leads of a blasting circuit. In any case, the result is a potentially dangerous situation. It is recommended that cellular telephones not be permitted to come into direct contact with, or near to, blasting circuits. The requirements for personal communications at or near blasting operations should be restricted to those means of communications having the knowledge and approval of those persons in charge of the blasting operation and operated in accordance with approved procedures. As an added precaution, the charging jack or points may be covered by a non-conducting tape or cover to avoid direct electric contact with a detonator or blasting circuit.

F. Low Power Handheld RF Sources in Close Proximity to Blasting Circuits

The recent proliferation of small, handheld, low power RF sources, (keyless entry systems, RF transmitters for remote control of equipment, garage door openers, wireless warehouse stock control systems, etc.), raises many issues concerning the safe use of these devices in the vicinity of blasting circuits or electro-explosive devices. First, it must be noted that these small low power RF sources fall into two general categories:

1. coded output pulsed RF transmitters
2. frequency modulated continuous output RF transmitters

The first type of device is a pulse modulated device with a very low duty cycle resulting in relatively low average power delivery to a nearby blasting circuit or electro-explosive device. The second type of device transmits continuously with the possibility of delivering relatively higher average power to a blasting circuit. Since the blaster may not have information regarding the type of RF source in use, the following recommendations are made:

1. If the low power handheld RF device is of unknown output mode, a safe distance of 11 feet should be observed for handheld transmitters of 2 watts output or less.
2. If it is necessary to use a low power handheld RF source at closer distances to blasting circuits or to electro-explosive devices, then a competent laboratory should be consulted and the RF source tested to determine the nature of its output and an assessment made to fix a safe distance between the particular type of RF source and the blasting circuit or electro-explosive device.

It must be noted that as in the case of cellular telephones, these small handheld RF sources also contain batteries which can result in the inadvertent application of DC current to a blasting circuit or to an electro-explosive device should such a device come into direct contact with a blasting circuit or electric detonator leadwire.

Inventory and stock management systems use bar code readers to read and record the bar codes on packaged products. Some bar code readers store the inventory or stock data in an on-board memory for downloading to a computer workstation at some later time. These units do not pose a threat to packaged electric detonators providing the construction of the bar code reader meets the electrical requirements for use in areas containing explosives. However, some bar code readers transmit the inventory data to a workstation by wireless means; these should not be used for magazine inventory or in receiving or shipping facilities where electric detonators are present. The RF transmitters built into the wireless bar code reader would be in operation in extremely close proximity to packaged electric detonators. Since the distance between the electric detonator and the wireless bar code reader is within the near field of the transmitter, the prediction of the response of the electric detonator to the EM field would be very difficult. Therefore, it is recommended to keep all RF transmitting devices of this type the appropriate safe distance from electric detonators.

G. RFID Tags and Tag Readers

Radio frequency identification systems are wireless systems incorporated into an asset or product in order to identify or track the asset or item. RFID systems date back to the late 1980s when they were used to identify livestock assets and in the early 1990s for timing sports events and for tracking assets such as sea-land containers. RFID systems consist of RFID tags attached to the item being tracked or managed, and readers, which wirelessly interrogate the tags for their pertinent data.

RFID tags may consist of either active tags which are self-powered and can transmit data-bearing signals autonomously or passive tags which require an external source to "awaken" and transmit data. Some passive tags also contain internal power sources to extend the range they can be read. The passive tags use the concept of reflected power or backscatter to send data back to the reader.

Many industries, services, and government organizations use RFID systems to track and communicate with persons or assets. As of 2006, RFID tags were included on all newly issued U.S. passports.

Both active and passive RFID tags exhibit very low RF power output; the active tag emitting the greater RF power for reading at a longer range. RF output power for active RFID tags for containers may be 10mW requiring a 10 foot distance from blasting circuits. The reflected RF energy from passive or battery-assisted RFID tags is in the microwatt range; too low to be of concern.

However, the RFID readers required to interrogate the tags, may have an RF power output of 4 watts in the U.S. under FCC requirements. An appropriate distance of 200 feet should be maintained between the RFID reader and electric detonators and the detonator's associated wiring.

H. RF Pickup Circuits

For the radio frequencies used in AM radio broadcasting and mobile operation, detonator and lead-wire layouts can act as RF circuits (receiving antennas).

1. Dipole Pickup Circuit

One sensitive RF pickup circuit that might be encountered in electric blasting operations is the dipole circuit. The most hazardous conditions exist when: 1) the circuit wiring and/or electric detonator leg wires are elevated several feet off the ground, 2) the length of this wiring is equal to one-half the wavelength of the radio wave or some multiple of it, and 3) the electric detonator is located at a point where the RF current in the circuit wiring is at a maximum. A specific example of this circuit is shown in Figure 1a where the wiring is equal to a half wavelength and the electric detonator is located at the center.

2. Long-wire Pickup Circuit

Another hazardous situation, similar to the dipole antenna, occurs when the electric detonator is at one end of wiring which: 1) is elevated in the air, 2) has a length equivalent to one-quarter the radio wavelength or an odd multiple of it, and 3) is grounded to earth through the electric detonator. This type of circuit is illustrated in Figure 1b.

Radio wavelengths in feet are approximately obtained by dividing 1,000 by the frequency in megahertz. Both of these circuits require that the lead or detonator wires be suspended above the ground, a situation not usually found in blasting operations. Both antennas achieve their maximum current pickup when they are (1) parallel to a horizontal transmitting antenna, FM, TV or amateur radio or (2) pointed toward a vertical antenna, AM mobile, cellular phone, etc.

3. Magnetic Loop Pickup Circuit

Another sensitive RF pickup circuit and one commonly encountered in blasting operations is the loop circuit shown in Figure 2. The loop circuit is sensitive to the magnetic portion of the electromagnetic field. In general, the larger the loop area, the greater the magnitude of the RF current pickup. The loop orientation for maximum pickup results when it is placed in the plane of the transmitting antenna. The loop configuration was selected for the calculations derived from the safe distance tables for one ohm electric detonators in the vicinity of AM broadcast transmitters and mobile transmitters, both employing vertical antennas. This pickup circuit was applied to AM broadcast, medium wave, and high frequency sources of RF emission. This condition could arise if one leg of the shot line were to be elevated above the ground while connected to the electric detonator with the shot line shunted forming an isosceles triangle pickup loop.

Since the magnetic loop pickup is a highly directional receiving antenna and is most sensitive to RF sources lying in the plane of the loop, it is most sensitive in the configuration shown in Figure 2b. The preferred case is shown in Figure 2a. It is to be noted that although shunting or shorting electric detonator leadwires is required, shorting of leadwires does not prevent induced current from RF fields from flowing through the detonator's bridgewire if the leadwires are unfolded and separated. In general, loop areas can be reduced by picking up both lead wires as in a duplex wire circuit and making wire splices as close to the ground as possible.

Antennas associated with the various radio services are shown in Figure 3. These sketches will help the blaster recognize common RF sources that may be near a blasting site.

FIGURE 1

DIPOLE AND LONG WIRE PICKUP CIRCUITS

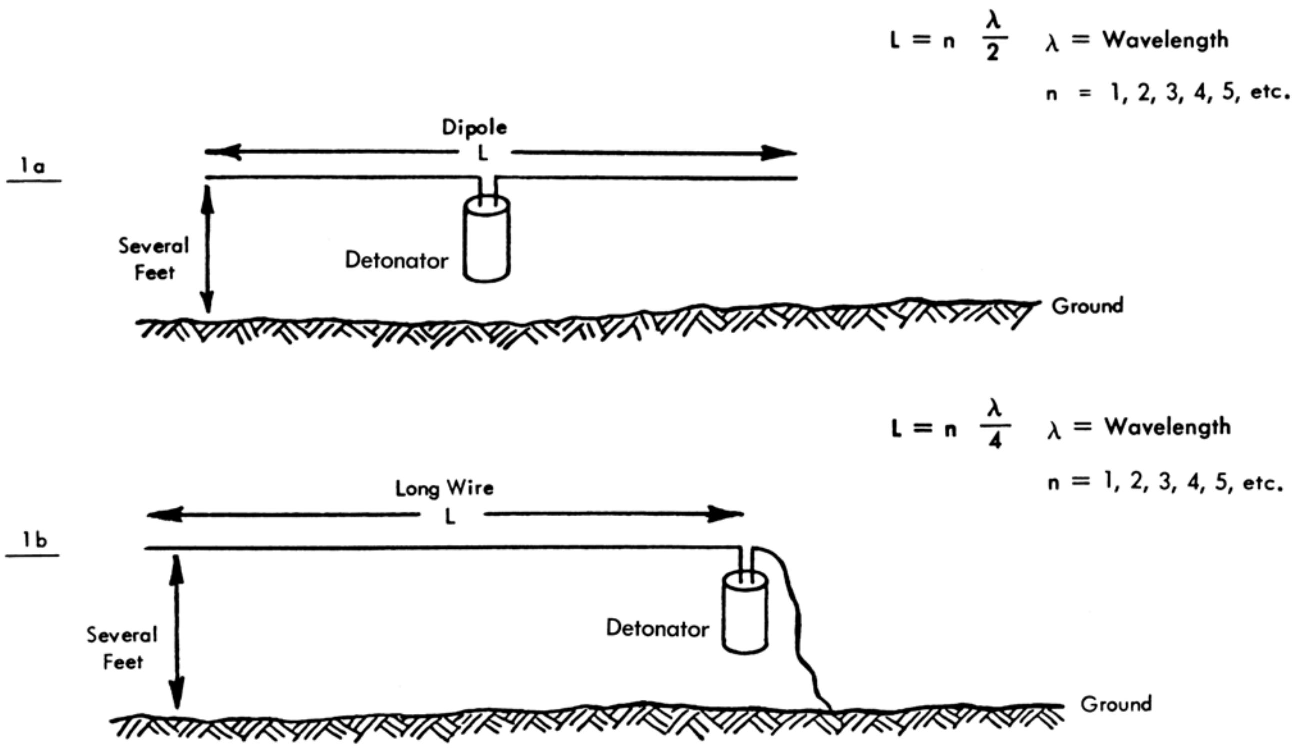
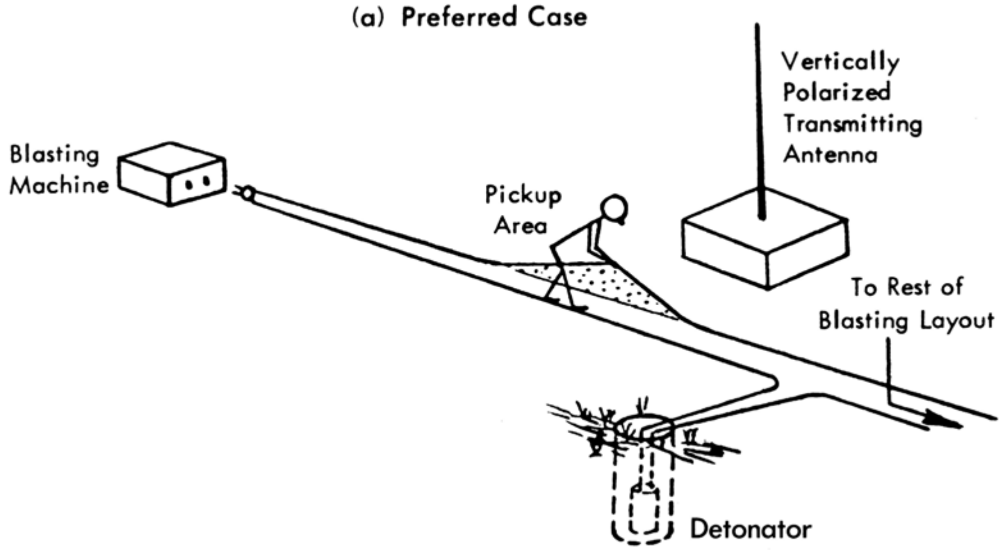


FIGURE 2

LOOP PICKUP CIRCUITS

(a) Preferred Case



(b) Acceptable but less desirable

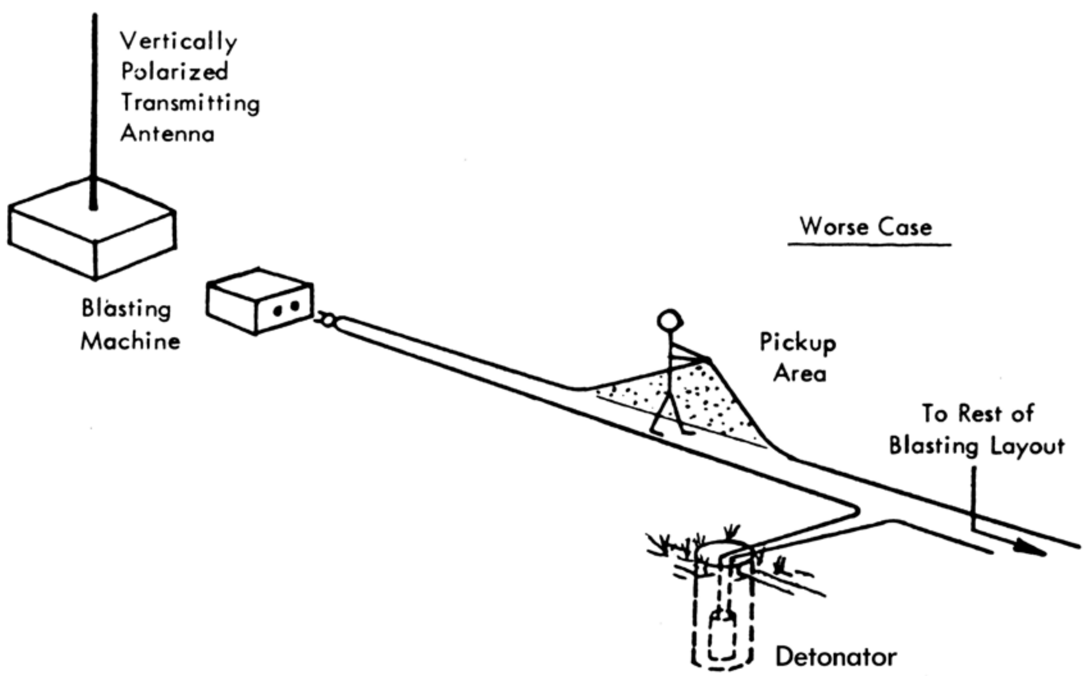
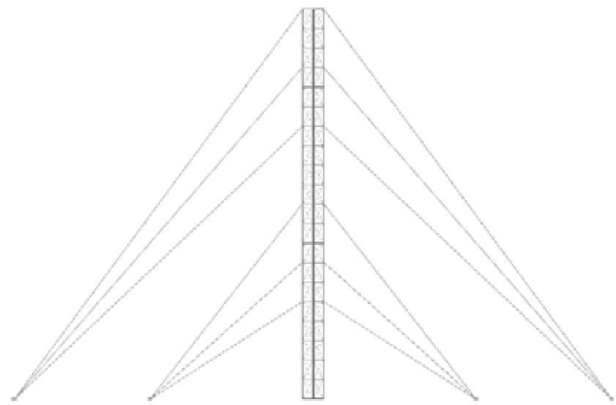
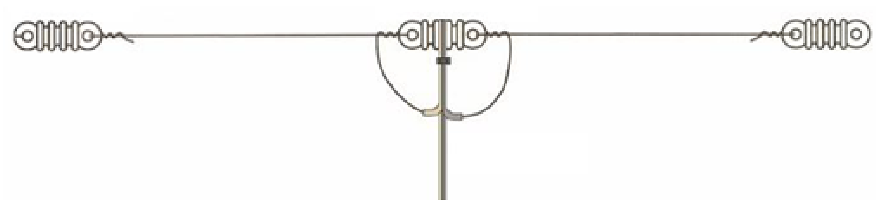


FIGURE 3
ANTENNA TYPES ASSOCIATED WITH THE RADIO SERVICES

AM Broadcasting Antenna
(Vertically Polarized)



Dipole Antenna
(Horizontally Polarized)



Beam Antenna
(Amateur High Frequency)

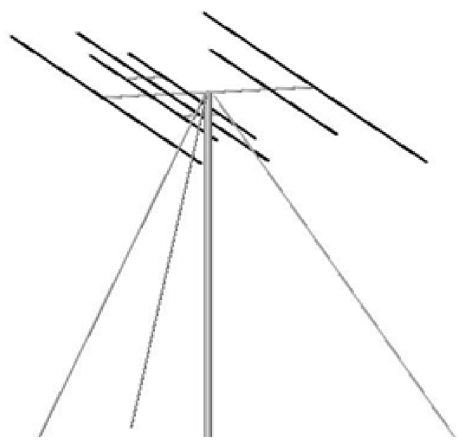
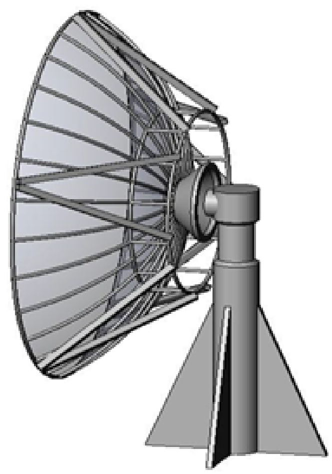
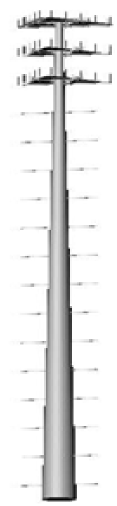


FIGURE 3
CONTINUED

Radar



Cellular Phone Service Antenna
(High-Gain Tower Mount)



Mobile Station

I. Military RF Installations

Military transmitters are becoming very numerous and they cover the frequency range from kilohertz to thousands of megahertz, often having extremely large power outputs.

Because of the nature of military work, much data on the systems is classified for security reasons. Installations may vary from day to day, and multiple transmitters may cause the energy to be pyramided at a particular location. If blasting must be done in the vicinity of military areas, it is strongly recommended that you communicate with the office of the commander in charge of the military establishment and explain your schedule to him. Such cooperation will be your best protection. Presenting this booklet to the military authorities will enable them to assist in determining whether or not your blasting operation will be safe from RF hazards.

A specific type of blasting operation where military radar is of major concern is that of offshore or marine blasting operations such as those operations that may take place during the exploration and production of offshore oil/gas resources, the removal of fixed or mobile offshore installations such as oil/gas drilling rigs and production platforms, and marine construction blasting or salvage operations.

The offshore waters are shared by many commercial and government interests and it is possible that military naval operations may take place in the vicinity of marine blasting. It is to be noted that certain types of military radars such as radars used to detect incoming hostile threats to surface ships have extremely high intensity and "paint" the surrounding area at wave height to detect surface skimming missiles.

The safe distance from this type of radar to an electrically-initiated blasting operation is 3 miles. It is recommended that if a blasting operation is planned offshore, that the cognizant authorities be informed of such operation so that adequate notification can be made to other mariners in the area. For example, the local districts of the United States Coast Guard publish a weekly supplement to the "Notice to Mariners". It is suggested that the commander of the Coast Guard district be notified of the time, location, and nature of the blasting operations in their district so that commanders of military vessels operating in the area are aware of the blasting work and can take precautions regarding the use of their radar equipment.

It is essential to be aware of the RF environment prior to commencing blasting operations. Some RF sources are not easily observed by mere line-of-sight.

J. General Precautions to Be Followed

The following list of precautions will further increase safety and reduce hazards associated with conducting electric blasting operations near RF energy sources.

1. When blasting electrically at a fixed location, such as a quarry, make sure that there are no radio transmitters located closer to your blasting site than the applicable separation recommended in the following section. Be on the lookout for the installation of new transmitters. Check them out before they go into service to insure that they will not pose a hazard to your blasting operation.

   When planning to blast electrically at a new location, as in construction work, inspect the area for RF transmitters before blasting is started. This will permit you to secure technically qualified assistance, if necessary, in planning your blasting procedures to minimize any RF hazard.

2. KEEP MOBILE TRANSMITTERS AWAY FROM BLAST SITES. Place adequate signs to remind operators to turn off transmitters when at the blast site. Where two-way radios, wireless data transmissions, and control radios are used, these devices should be tested and certified for use prior to installation. In all cases, the minimum separation specified in Table 3, for the type transceiver used, should be maintained.

3. Use the higher frequency bands, 450 MHz and above, for mobile transmitters if there is a choice. RF pickup is less efficient at these frequencies than at the lower frequencies.

4. Avoid large loops in blasting wiring by running lead wires parallel to each other and close together (preferably twisted pairs).

5. If loops are unavoidable, keep them small and orient them broadside towards the transmitting antenna (see Figure 2a).

6. Keep wires on the ground in blasting layouts. Bare connecting points should be elevated slightly to prevent current leakage.

7. Keep all lead lines out of the beam of directional devices such as radar or microwave relay stations.

K. Monitoring and Alternate Means of Blast Initiation

For the cases not specifically covered by the tables, for cases where there may be multiple RF sources present of varying power and frequency, and marginal cases where doubt exists as to the safety of electrically-initiated blasting, broadband monitoring of the RF field intensity at the blast site should be performed along with consultation with competent experts. The measurement of RF fields should not be attempted by persons unfamiliar with RF field theory as many pitfalls exist that could lead to erroneous results. As an alternative, there are devices available on the market such as exploding wire detonators, exploding foil initiators, electronic detonators, and deflagration-to-detonation detonating devices that are designed to be less susceptible to RF stimuli than conventional electric blasting caps. One of these devices could be used in place of conventional commercial blasting caps, or a means of non-electrical initiation used.

L. Transportation

All available evidence indicates that radio energy is not a hazard in the transportation of electric detonators so long as they are in their original containers. This is because the wires are coiled or folded in a manner which provides highly effective protection against current induction. Furthermore, almost all truck bodies and freight cars are made of metal and this virtually eliminates the penetration of RF energy. Since the barrier laminate construction of the IME 22 container contains a layer of steel or sheet metal, shielding of the detonators contained within from RF energy is provided by the container's design (See SLP 22).

If vehicles equipped with radio transmitters are used in transporting electric detonators to or from a job, it is recommended that (1) they be carried in a closed metal box, and (2) the transmitter be turned off when the detonators are either being put into or taken out of the box. To protect against shock and friction, the metal box should be lined with a soft material such as wood or sponge rubber.

It is recognized that the instantaneous communication capability of vehicle mounted, two-way radios is a valuable safety asset if a critical situation arises on an explosive material delivery truck or on construction jobs, at mining operations, etc. where electric blasting is practiced. However, when a vehicle is driven or parked closer to a blast site than the recommended separation in Table 3, the possibility exists that a person, unaware of the potential hazard or not thinking of the vehicle's location, may attempt to use the radio transmitter.

To prevent such accidental transmission, a "positive means" of preventing transmission should be employed.

The preferred "positive means" is to physically disconnect the two-way radio from its power supply. If this is not practical, the switch operated microphone should be physically disconnected from the radio. If this also is not practical, a stop should be placed under or a cover over the transmit switch or the switch secured in the "off" position by a piece of masking tape so that anyone attempting to make a transmission will be made aware or reminded that he should not transmit from that location.

PART II

Tables of Recommended Safe Distances from RF Sources for Conventional 1 Ohm Electric Detonators

These tables of distances are designed for the convenience of the commercial blaster. The selected groupings include all the obvious types of RF transmitters that will be encountered around blasting sites.

These tables were derived from analytical "worse-case" calculations. They are based on an assumed 40-milliwatt no-fire level of commercial detonators of nominal one ohm resistance. Actual field tests have shown that these tables are conservative as would be expected. Because of the uncertainties involved in field tests as to the efficiency of RF energy pickup and its delivery to the detonator, we strongly recommended that these tables be followed. If these tables present distances which are operationally inconvenient to use, we suggest field tests be made by expert consultants and the procedures detailed for providing minimum RF pickup be adhered to.

The data upon which these tables are based were derived by Franklin Institute Research Laboratories for the Institute of Makers of Explosives (IME). Subsequent review and analysis by representatives of the American National Standards Institute and the IEEE C95.4 Committee on Radio-Frequency Radiation Hazards resulted in better clarification and continuity of the Tables. These modifications enabled the IME Pub. No. 20 to be accepted as a guide by the C95 Committee. The Franklin Research Laboratories reports pertinent to this work include:

F-B2256 – Investigation of the RF Hazards to Electric Blasting Caps, October 1968;

F-B2256 – RF Pickup of Antennas Simulating Blasting Wire Configurations Measurement Results, October 1968;

F-C195 1 – Measurement of the RF Coupling between an Antenna Simulating a Blasting Wire Configuration and Nearby Mobile Transmitting Antennas, October 1968.

FIRL Report F-C3102 – "Evaluation and Determination of Sensitivity of Electromagnetic Interactions of Commercial Blasting Caps", R. H. Thompson, August 1973.

For further information, please contact:

Franklin Applied Physics
98 Highland Avenue
P.O. Box 313
Oaks, PA 19456
Phone: (610) 666-6645
Fax: (610) 666-0173
Electronic Mail: info@FranklinPhysics.com

All of the following tables, where transmitter power or effective radiated power is listed for specific types of broadcasting or radio transmission services, were updated from the *Code of Federal Regulations* 47, "Telecommunications", revised as of Oct. 1, 2010. Other sources include the United States Coast Guard covering aids to marine navigation, and the American Radio Relay League covering amateur radio transmission. It should be noted that Table 14 listing the various types of radio transmission services is a summary only and does not include every conceivable type of RF source. Also, the radio frequency spectrum and its allocation are subject to change as older technologies are no longer required and new types of information transmission are introduced. It is essential that the blaster use the latest version of all safety library publications.

For additional information on the subject of electric detonators and RF hazards to electrically-initiated blasting:

IEEE Recommended Practice for Determining Safe Distances from Radio Frequency Transmitting Antennas when using Electric Blasting Caps during Explosive Operations, ANSI/IEEE Std C95.4-2002.

A Study of RF Hazards at Low and Medium Frequencies to Blasting in Underground Coal Mines, Mining Research Contract Report, Bureau of Mines, U.S. Dept. of the Interior, January 1985.

Thompson, R. H., "Safe Distances for Blasting Wiring from Commonly Encountered Underground Electromagnetic Energy Sources", Final Report C5490, Franklin Research Center, Philadelphia, PA, September 1983.

MIL-STD-1512, Military Standard, "Electroexplosive Subsystems, Electrically Initiated, Design Requirements and Test Methods, July 1963.

MIL-STD-1576, Military Standard, Electroexplosive Subsystem Safety Requirements and Test Methods for Space Systems, July 1984.

Table 1
Recommended Distances for One Ohm Electric Detonators from Commercial AM Broadcast Transmitters, Small Loop Pickup, 0.535 to 1.605 MHz (Figure 4)

Transmitter Power [1] (Watts)	Minimum Distance (Feet)
Up to 4,000	720
5,000	800
10,000	1,130
25,000	1,790
50,000 [2]	2,500
100,000	3,600
500,000	8,000

(1) Power delivered to transmitting antenna.

(2) 50,000 watts is the present maximum power of U.S. Class A broadcast transmitters in this frequency range.

Table 2
Recommended Distances for One Ohm Electric Detonators from Transmitters up to 50 MHz (Excluding AM Broadcast) Calculated For a Specific Loop Pickup Configuration [1] [2] (Figure 5)

Transmitter Power [3] (Watts)	Minimum Distance (Feet)
100	790
200	1,120
500	1,770
1,000	2,500
1,500	3,070
5,000	5,590
50,000	17,700
500,000 [4]	55,900

(1) Based on the configuration shown in Fig. 2b, using 22.8 MHz, which is the most sensitive frequency.

(2) This table should be applied to International Broadcast Transmitters (shortwave), in the 10-25 MHz range.

(3) Power delivered to antenna.

(4) Present maximum for International Broadcast.

Table 3
Recommended Distances for One Ohm Electric Detonators from RF Sources such as Fixed and Mobile Transmitters Including Cellular Telephone Service, Amateur Radio and Citizens' Band

MINIMUM DISTANCE (Feet)

Transmitter[1] Power (Watts)	MF 1.7 to 3.4 MHz Fixed, Mobile, Maritime	HF 28 to 29.7 MHz Amateur	VHF 35 to 36 MHz Public Use 42 to 44 MHz Public Use 50 to 54 MHz Amateur	VHF 144-148 MHz Amateur 150.8-161.6 MHz Public Use	UHF 450 to 470 MHz Public Use Cellular Telephones Above 800 MHz
1	15	47	37	12	8
3	25	81	64	21	14
5	33	105	82	27	18
10	46	148	116	38	25
50	102	331	259	85	55
100	144	468	366	120	78
180 (2)	193	627	491	161	104
200	204	661	518	170	110
250	228	739	579	190	123
500 (3)	322	1045	818	268	174
600 (4)	353	1145	897	294	190
1,000	455	1,478	1,157	379	245
1,500(5)	557	1,810	1,417	464	300
10,000(6)	1,438	4,673	3,659	1,198	775

Table 3a (Continued)
Recommended Distances for One Ohm Electric Detonators from Citizens Band, Class D Transmitters 26.965 MHz (Channel 1) 27.405 MHz (Channel 40)

	Recommended Minimum Distance	
Type	**Hand-Held**	**Vehicle-Mounted**
Double Sideband – 4 Watts maximum Transmitter Power	5 ft	65 ft
Single Sideband – 12 Watts (Peak Envelope Power)	20 ft	110 ft

1) Power delivered to the antenna.

2) Maximum power to two-way mobile units in VHF (150.8 or 161.6 MHz range) and for two-way mobile and fixed station units in UHF (450 to 460 MHz range).

3) Maximum power for major VHF two-way mobile and fixed station units in 35 to 44 MHz range.

4) Maximum power for two-way fixed station units in VHF (150.8 to 161.6 MHz range).

5) Maximum power for amateur radio mobile use.

6) Maximum power for some base stations in 42 to 44 MHz band and 1.6 to 1.8 MHz band.

Table 4
Recommended Distances for One Ohm Electric Detonators from VHF TV and FM Broadcast Transmitters (Figure 6)

Effective Radiated Power (Watts) (1) (2) (3)		Minimum Distance (Feet)	
	Channels 2 to 6	**FM Radio**	**Channels 7 to 13**
Up to 1,000	820	667	502
10,000	1,450	1,190	892
45,000	2,121	NA	NA
100,000	2,580	2,115	1,585
160,000	NA	NA	1,780
316,000	3,450	2,820	2,130
1,000,000	4,600	3,770	2,820
10,000,000	8,190	6,690	5,020

(1) Present maximum effective radiated power for Class C FM radio is **100,000 Watts.**

(2) Present maximum ERP for Channels 2-6, 100,000 Watts video, 10,000 Watts audio and **45,000 Watts digital**.

(3) Present maximum ERP for Channels 7-13, 316,000 Watts video, 31,600 Watts audio and **160,000 Watts digital.**

Table 5
Recommended Distances for One Ohm Electric Detonators from UHF TV Transmitters (Figure 7)

Effective Radiated Power (Watts)	Minimum Distance (Feet)
Up to 10,000	600
1,000,000 (1)	2,000
5,000,000 (1)	3,000

(1) Present maximum power for UHF TV Channels 14 to 36 and 38 to 51 is 5,000,000 Watts audio, 1,000,000 Watts digital. As of 12 June 2009, all U.S. full power analog TV stations ceased broadcasting and replaced analog transmissions with digital broadcasting on the same transmission channel.

Figure 4. Recommended Distance from Commercial AM Broadcast Transmitters (0.535 to 1.605 MHz)

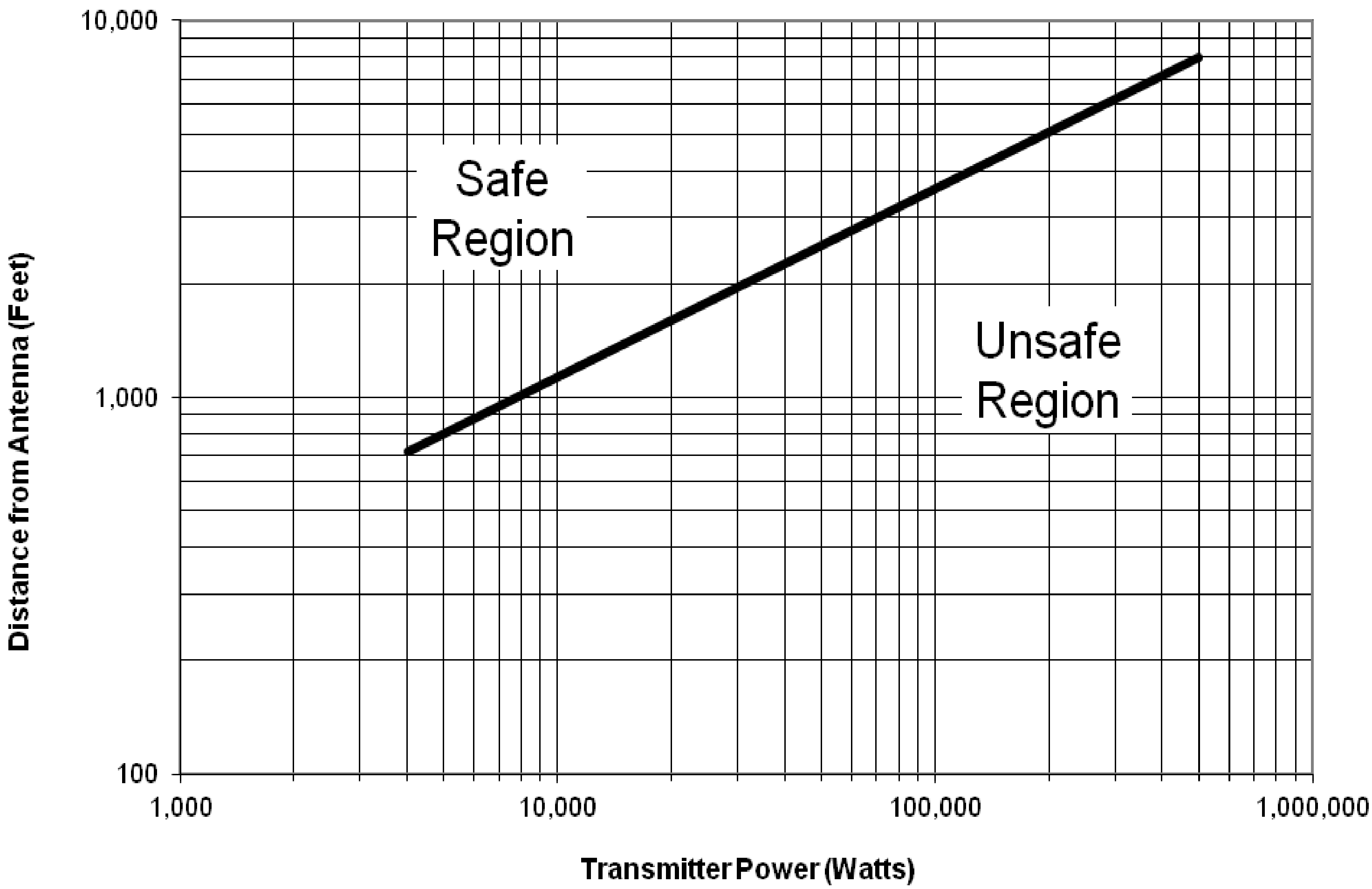


Figure 5. Recommended Distance from Transmitters up to 50 MHz (Excluding AM Broadcast)

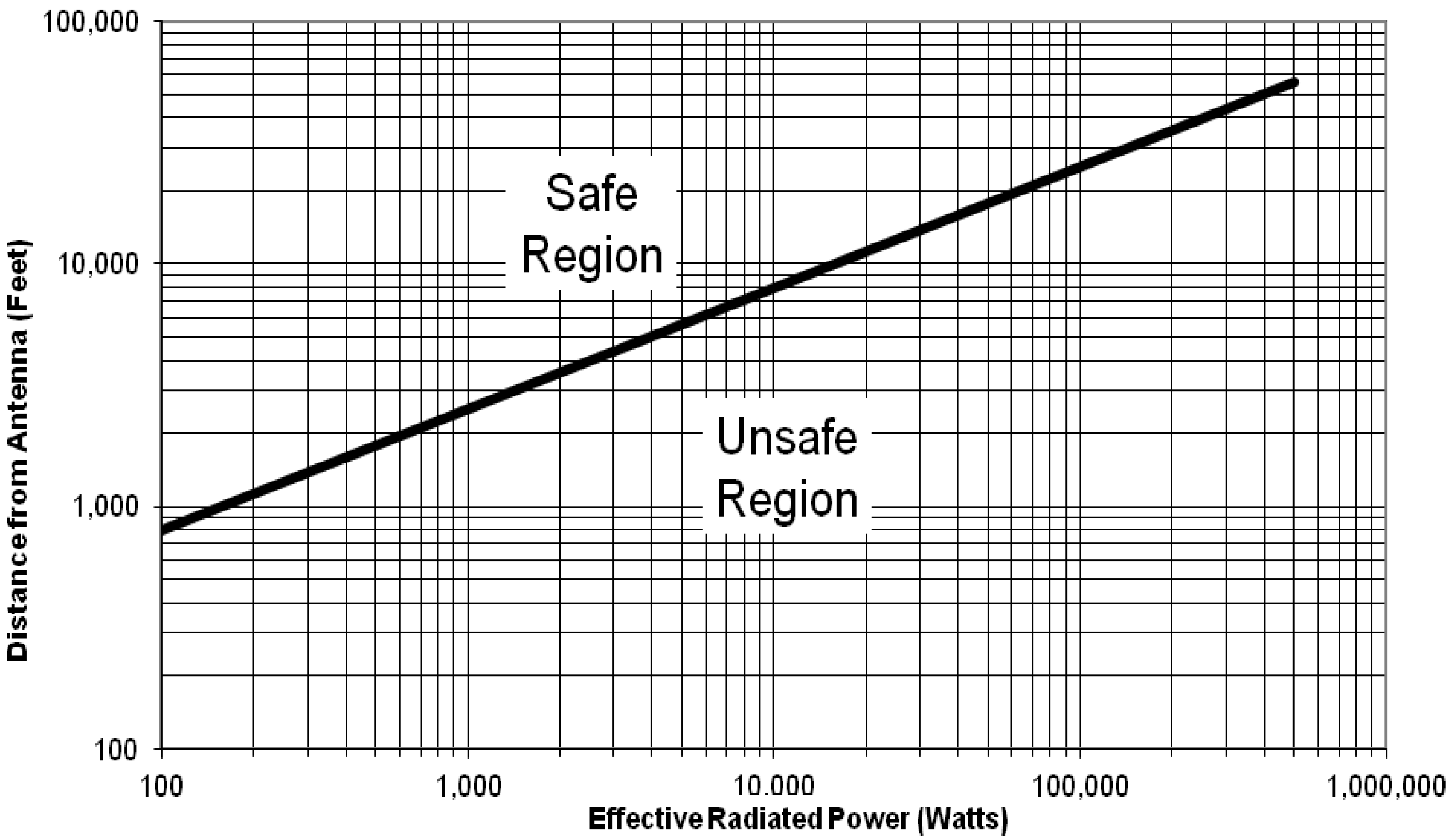


Figure 6. Recommended Distance from VHF TV and FM Transmitters

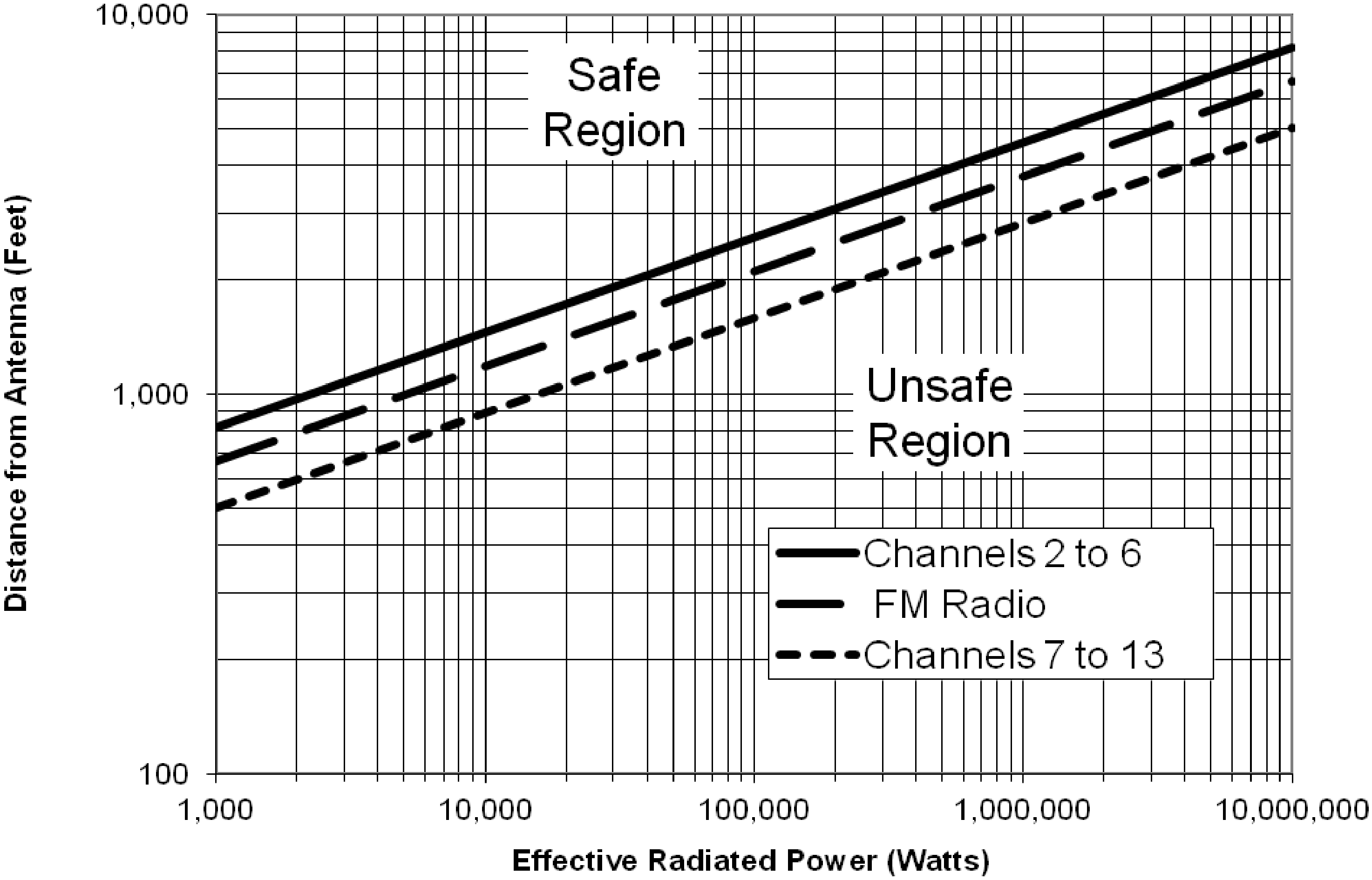
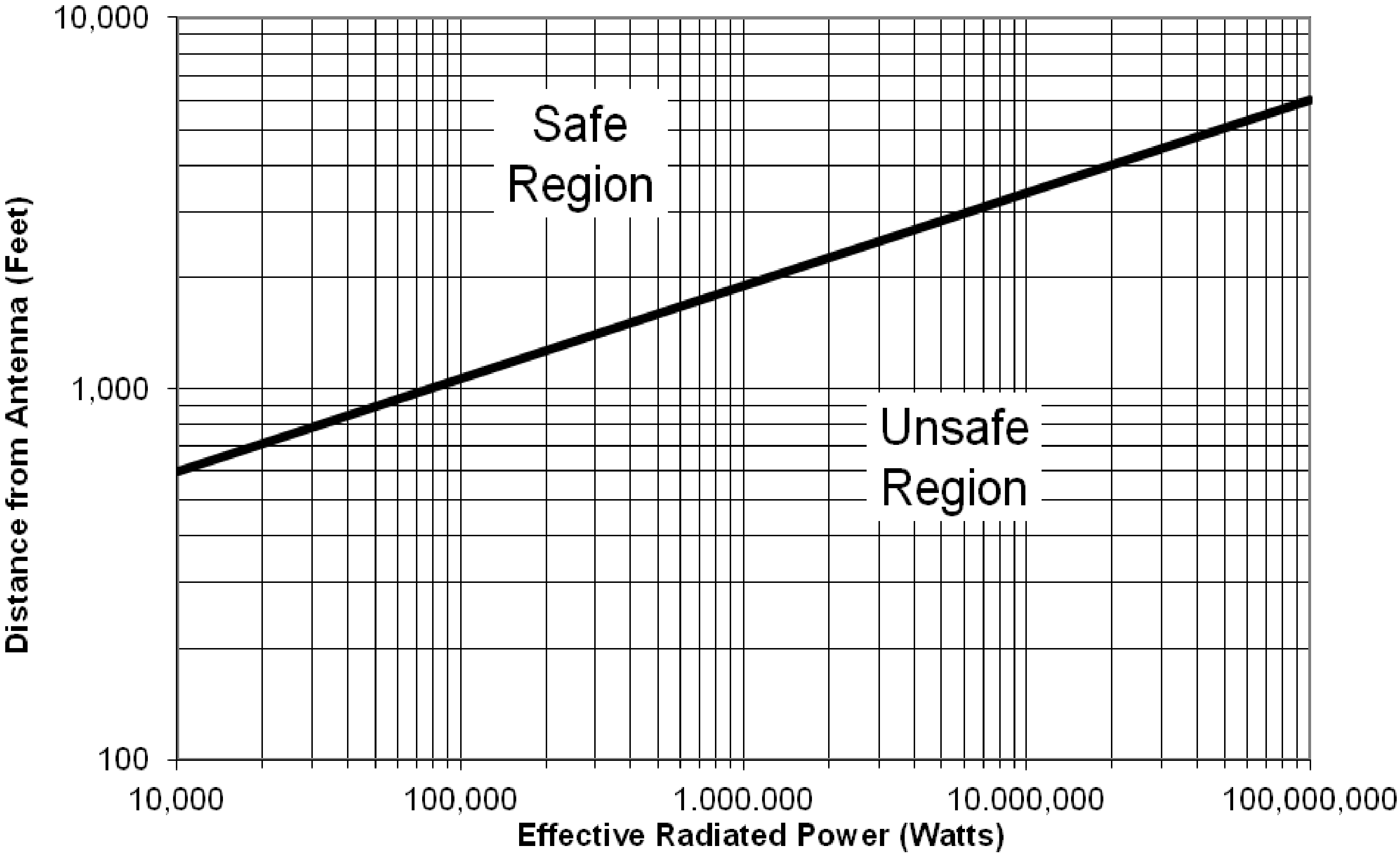


Figure 7. Recommended Distance from UHF TV Transmitters (Channel 14 and Higher)



A. Radar and Safe Distances for One Ohm Electric Detonators

Occasionally 10 cm. (3,000 MHz) and 3 cm. (9,000 MHz) Maritime Radionavigation Radar will be encountered at blasting sites. This radio frequency source may be characterized by a high effective average radiated power*, in some cases exceeding 50,000 watts. While outside the beam, no hazard exists at the blasting site. Generally, if the boat or ship can be seen that is using radar, one can assume that they may be within the beam.

Generally the strength and potential hazard of the radar sources will depend on the type of boat or ship it is on. The following table gives some guidelines as to what may be encountered at river, harbor or ocean blasting sites.

Table 6
Recommended Distances for One Ohm Electric Detonators from Maritime Radionavigational Radar

Type of Service	Effective Radiated Power , ERP(Watts)*	Wave length (cm)	Minimum Distance (Feet)
Small Pleasure Craft	500	3	20
Harbor Craft, River Boats, etc.	5,000	3	50
Large Commercial Shipping	50,000	3 & 10	300

The above tables should be used only if the exact nature of the radar hazard is understood. In cases where an uncertainty exists as to the nature of the radar signal as well as ground scatter and reflection of the radar signal, a recommended minimum distance of 1,000 feet should be maintained from the radar antenna.

Long-range radar (non-military) of frequency 1.3 to 1.35 GHz (wavelength 0.2m) can have a million watts peak power (100,000 watts average). This is hazardous within one mile. Consult local authority.

*Effective Radiated Power = (Maximum antenna gain x antenna input power)

Table 6A
Recommended Distances for One Ohm Electric Detonators from Radio Navigation Beacons

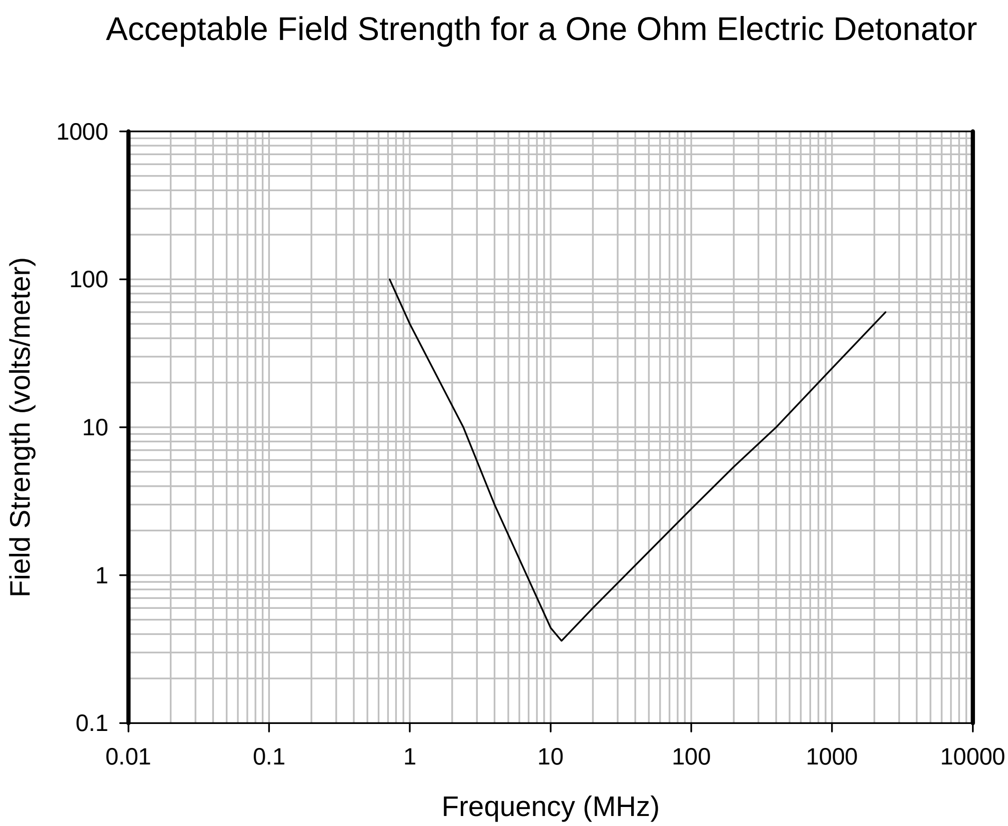
Type of Service	Power (Watts)	Frequency (MHz)	Minimum Distance (Feet)
Loran-C	1,000,000	0.1	650
VOR (VHF Omni-directional radio)	100	110	110
Localizer	100	110	110
Glide Slope	15	315	25

B. Safe Field Strength as a Function of Frequency

The purpose of this section is to offer a guideline on the acceptable electric field strength, (E Field), at a location where a conventional electric detonator may be expected to be present with respect to the source or sources of radio frequency, (RF), radiation.

IME believes that it would be useful to provide this data to manufacturers and developers of RF emitting devices that may wish to design their equipment for use near blasting circuits and electric detonators. The following log-log plot shows the acceptable electric field strength, (E Field in volts/meter), as a function of frequency in Megahertz (MHz), that the one ohm electric detonators can be exposed to while minimizing the risk of inadvertent initiation due to energy extracted by the detonator and its wiring from an RF field. This chart is a plot of the maximum acceptable RF electric field strength from sources of electromagnetic energy at a location where any part of the electric detonator or attached wiring is expected to be present with respect to the RF source or sources.

Figure 8



C. Multiple Sources of RF in the Vicinity of Electric Blasting Circuits

Where multiple sources of RF are present, the ratio of actual measured or computed field strength, (volts/meter), divided by the maximum acceptable field strength at that frequency, (volts/meter), can be formed for each RF source. Squaring each ratio and summing those squared ratios for each RF source should produce a value less than one to consider the electric detonator's location with respect to multiple RF sources as having a very low likelihood of inadvertent initiation.

$$(E_1/E_{1max})^2 + (E_2/E_{2max})^2 + (E_3/E_{3max})^2 + \ldots + (E_n/E_{nmax})^2 < 1$$

Where:

$E_1, E_2, E_3, \ldots E_n$ are the measured or computed electric field strengths at the detonator location with respect to the RF sources and;

$E_{1max}, E_{2max}, E_{3max}, \ldots E_{nmax}$ are the maximum acceptable electric field strengths for that frequency from the above plot.

Also, it must be clear that the above plot applies to far field conditions only, that is, circumstances where the electric detonator and its lead-wires is separated from the RF source; (i), by a distance of at least a few wavelengths and (ii), at a distance larger than the maximum physical dimension of the transmitting antenna. At closer distances within the transmitting antenna's near field, the field can be very difficult to predict and simple equations may not accurately represent the source and receiver or the detonator's energy extraction from the electromagnetic fields. Computer-based numerical methods are usually employed in such cases and the results can vary greatly from those predicted by far field equations.

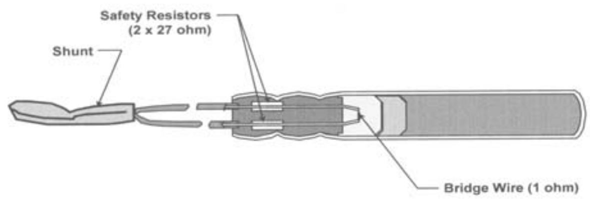
It is not the intent of the Institute of Makers of Explosives or its member companies to publish design specifications or make recommendations concerning the design of equipment producing non-ionizing radiation used in the vicinity of electric detonators and blasting circuits. The above referenced plot is to serve as a guideline for determining the design and administrative controls necessary to reduce the likelihood of the inadvertent initiation of electric detonators by RF fields.

PART III

Tables of Recommended Safe Distances from RF Sources for 50 Ohm Oilfield Resistorized Electric Detonators

The 50 ohm resistorized electric detonator is frequently used in the upstream oil and gas industry at the wellsite for the downhole initiation of perforating guns, explosive cutters for pipe recovery, backoff shots and with other types of explosive tools used in oil and gas wells during wireline-conveyed operations. This type of electric detonator, equipped with a pair of series resistors in the detonator's header, provides some degree of safety above conventional one ohm electric detonators by requiring a higher current to initiate the device. The American Petroleum Institute's "Recommended Practice for Oilfield Explosives Safety", API Recommended Practice 67, second edition, May 2007, specifies that the resistorized electric detonator be considered to be the minimum level of protection against inadvertent initiation of the detonator that should be used at the wellsite. A cross-sectional diagram of a resistorized electric detonator is depicted in Figure 8.

Figure 9 50 Ohm Resistorized Electric Detonator

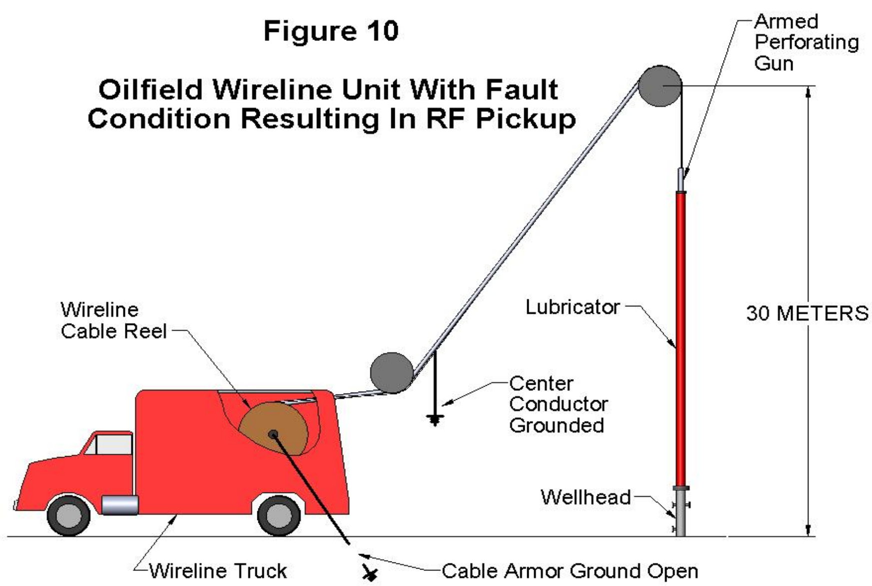


In order to obtain "no-fire" current or "no-fire" power data for these specialized detonators to apply to the equations computing the safe distances from radio frequency sources, it was necessary to conduct "one-shot" tests on samples of the detonators supplied by different manufacturers. The result was a wide range of "no-fire" current levels ranging from 271 milliamps to 45 milliamps and "no-fire" power levels ranging from 4.0 watts to 0.1 watt. The reason this occurred is that the resistorized electric detonators exhibited differing failure modes. In some cases, series resistors would open at low current levels, rendering the device under test a dud. In keeping with the U.S. Department of Defense testing standards for electro-explosive devices, any application of a low electrical current which results in rendering the initiating device useless for its intended use, (whether the device fires or not), is considered to be a failure. Thus the "no-fire" power level that was applied for use in the safe distance tables in this document for 50 ohm oilfield electric detonators was the lowest "no-fire" power observed with a 0.999 probability of not firing with a 95% confidence level; namely 0.1 watt.

Furthermore, if the blasting circuit or electric detonator was to be considered a pickup circuit extracting energy from a radio frequency field, then the configuration that could be encountered in oilfield operations had to be examined. In the case of AM broadcast and medium wave RF up to 50 MHz, the small magnetic loop model used for the one ohm electric detonator was abandoned and replaced by a short dipole pickup model instead. The reason was that the oilfield electric detonator could be connected to a wireline unit at the wellsite with an armored cable elevated 100 feet or so vertically to run the tool string into a lubricator assembly attached to the wellhead. For a nearby vertically polarized AM broadcast transmitter, this was considered to be a sensitive configuration if the ground was opened on the cable armor, the wireline's center conductor grounded, and an electric detonator connected between the two. Figure 9 depicts this ground fault that could extract RF energy from an electro-magnetic field.

Figure 10

Oilfield Wireline Unit With Fault Condition Resulting In RF Pickup



Recommended Tables of Safe Distances from RF sources for 50 Ohm Resistorized Oilfield Electric Detonators

Table 7
Recommended Distances for 50 Ohm Oilfield Electric Detonators from Commercial AM Broadcast Transmitters, 0.535 to 1.605 MHz

Transmitter Power (Watts)[1]	Minimum Distance (Feet)
Up to 4,000	960
5,000	1,072
10,000	1,516
25,000	2,400
50,000[2]	3,391
100,000	4,794
500,000	10,720

[1] Power delivered to the transmitting antenna.
[2] 50,000 watts is the present maximum power of U.S. broadcast transmitters in this frequency range.

Table 8
Recommended Distances for 50 Ohm Oilfield Electric Detonators from Transmitters up to 50 MHz (Excluding AM Broadcast) Calculated for a Dipole Pickup Configuration[1 2]

Transmitter Power (Watts)[3]	Minimum Distance (Feet)
100	446
200	531
500	667
1,000	794
1,500	878
5,000	1,187
50,000	2,110
500,000[4]	3,753

[1] Based on the configuration shown in Figure 2b, using 22.8 MHz which is the most sensitive frequency.
[2] This table should be applied to International Broadcast Transmitters (shortwave), in the 10-25 MHz range.
[3] Power delivered to the antenna.
[4] Present maximum for International Broadcast.

Table 9
Recommended Distances for 50 Ohm Oilfield Electric Detonators from RF Sources such as Fixed and Mobile Transmitters
Include Cellular Telephone Service, Amateur Radio and Citizen's Band
Minimum Distance (Feet)

Transmitter[(1)] Power (Watts)	MF 1.7 to 3.4 MHz Fixed, Mobile Maritime	HF 28 to 29.7 MHz Amateur	VHF 35 to 36 MHz Public Use 42 to 44 MHz Public Use 50 to 54 MHz Amateur	VHF 144 to 148 MHz Amateur 150.8 to 161.6 MHz Public Use	UHF 450 to 470 MHz Public Use Cellular Telephones above 800 MHz
1	7	29	23	6	3
3	11	50	39	11	5
5	14	65	50	14	6
10	20	91	71	19	8
50	43	204	158	42	18
100	61	288	223	60	25
180 [(2)]	82	386	299	80	33
200	86	407	315	84	35
250	96	455	352	94	39
500 [(3)]	136	643	498	133	54
600 [(4)]	149	704	545	145	60
1,000	192	909	704	188	77
1,500 [(5)]	235	1,113	862	230	94
10,000 [(6)]	607	2,874	2,225	592	241

Table 9a (Continued)
Recommended Distances for 50 Ohm Oilfield Electric Detonators from Citizen's Band, Class D Transmitters
26.965 MHz (Channel 1) to 27.405 MHz (Channel 40)

	Recommended Minimum Distance	
Type	**Hand-Held**	**Vehicle-Mounted**
Double-Sideband – 4 Watts maximum Transmitter Power	4 feet	42 feet
Single Sideband – 12 Watts (Peak Envelope Power)	13 feet	70 feet

(1) Power delivered to the antenna.
(2) Maximum power to two-way mobile units in VHF, (150.8 to 161.6 MHz range), and for two-way mobile and fixed station units in UHF, (450 to 460 MHz range)
(3) Maximum power for major VHF two-way mobile and fixed station units in 35 to 44 MHz range.
(4) Maximum power for two-way fixed station units in VHF, (150.8 to 161.6 MHz range).
(5) Maximum power for amateur radio use.
(6) Maximum power for some base stations in 42 to 44 MHz band and 1.6 to 1.8 MHz band.

Table 10

Recommended Distances for 50 Ohm Oilfield Electric Detonators from VHF TV and FM Broadcasting Transmitters

Effective Radiated Power (ERP)[1,2,3]		Minimum Distance (Feet)	
	Channels 2 to 6	**FM Radio**	**Channels 7 to 13**
Up to 1,000	853	670	480
10,000	1,520	1,200	850
45,000	2,210	NA	NA
100,000	2,700	2,120	1,511
160,000	NA	NA	1,700
316,000	3,600	2,850	2,014
1,000,000	4,800	3,770	2,690
10,000,000	8,600	6,700	4,780

Table 11

Recommended Distances for 50 Ohm Oilfield Electric Detonators from UHF TV Transmitters

(Effective Radiated Power (Watts)	Minimum Distance (Feet)
Up to 10,000	520
1,000,000[1]	1,640
5,000,000[1]	2,500

[1] Present maximum ERP for UHF TV Channels 14 to 36 and 38 to 51 is 5,000,000 Watts video, 500,000 Watts audio, and 1,000,000 Watts digital. As of 12 June 2009, all U.S. full power analog TV stations ceased broadcasting and replaced analog transmissions with digital broadcasting on the same transmission channel.

Radar and Safe Distances for 50 Ohm Oilfield Electric Detonators

Occasionally 10 cm. (3,000 MHz) and 3 cm. (9,000 MHz) Maritime Radionavigation Radar will be encountered at blasting sites. This radio frequency source may be characterized by a high effective average radiated power*, in some cases exceeding 50,000 watts. While outside the beam, no hazard exists at the blasting site. Generally, if the boat or ship can be seen that is using radar, one can assume that he may be within the beam.

Generally the strength and potential hazard of the radar sources will depend on the type of boat or ship it is on. The following table gives some guidelines as to what may be encountered at river, harbor or ocean blasting sites.

[1] Present maximum ERP for Class C FM radio is 100,000 Watts.
[2] Present maximum ERP for Channels 2-6, 100,000 Watts video, 10,000 Watts audio, and 45,000 Watts digital.
[3] Present maximum ERP for Channels 7-13, 316,000 Watts video, 31,600 Watts audio, and 160,000 Watts digital.

Table 12
Recommended Distance for 50 Ohm Oilfield Electric Detonators from Maritime Radionavigational Radar

Type of Service	Effective Radiated Power (Watts)*	Wavelength (cm.)	Minimum Distance (Feet)
Small Pleasure Craft	500	3	13
Harbor Craft, River Boats, Etc.	5,000	3	32
Large Commercial Shipping	50,000	3 & 5	190

The above tables should be used only if the exact nature of the radar hazard is understood. In cases where an uncertainty exists as to the nature of the radar signal as well as ground scatter and reflection of the radar signal, a recommended minimum distance of 1,000 feet should be maintained from the radar antenna.

Long-range radar (non-military) of frequency 1.3 to 1.35 GHz (wavelength 0.2m) can have a million watts peak power (100,000 watts average). This is hazardous within one mile. Consult local authority.

*Effective Radiated Power = (Maximum antenna gain x antenna input power)

Table 12A
Recommended Distances for 50 Ohm Oilfield Electric Detonators from Radio Navigation Beacons

Type of Beacon	Power	Frequency	Minimum Distance (Feet)
Loran-C	1,000,000	0.1	412
VOR	100	110	70
Localizer	100	110	70
Glide Slope	15	315	16

PART IV

Radio Frequency Sources and Definitions

A partial list of RF sources is given in Table 13 and standard definitions related to radio frequency sources are given in Table 14 and SLP-12 Glossary Terms.

Table 13
Radio Transmitting Services
(Partial List)

Type of Service	Frequency (Megahertz)	Wavelength (feet)	Maximum Transmitter Power (Watts)	Safe Distance Table for One Ohm Detonators	Safe Distance Table for 50 Ohm Detonators
Commercial					
Standard AM Broadcast	0.535 – 1.705	1820 - 577	50,000	1	7
FM broadcast	88 - 108	11.2 – 9.1	100,000 (FM Zone II ERP)(1)(2)	4	10
Television Broadcast (channels 2 to 6)	54 - 88	18.2 – 11.2	100,000 (Analog ERP)(1)	4	10
Television Broadcast (Channels 7 to 13)	174 - 216	5.6 – 4.5	316,000 (Analog ERP)(1)	4	10
Television Broadcast (Channels 14 to 69)	470 - 806	2.1 – 1.22	5,000,000 (Analog ERP)(1)	5	11
Amateur/Citizen's Band					
160 meter band	1.8 – 2.0	545 - 490	1,500	2	8
80 meter band	3.5 – 4.0	280 - 246	1,500	2	8
40 meter band	7.0 – 7.3	140 - 135	1,500	2	8
30 meter band	10.1 – 10.15	97	200 (peak envelope power)	2	8
20 meter band	14.0 – 14.35	70.0 – 68.2	1,500	2	8
17 meter band	18.068 – 18.168	54.4	1,500	2	8
15 meter band	21.0 – 21.45	46.9 – 46.3	1,500	2	8
12 meter band	24.89 – 24.99	39.4	1,500	2	8
Citizen's Band	26.965 – 27.405	36.6 – 36.0	4 watts AM or 12 watts PEP SSB	3a	9a
10 meter band (mobile)	28.0 – 29.7	35.1 - 33.0	1,500	3	9
10 meter band (fixed)	28.0 - 29.7	35.1 – 33.0	1,500	2	8
6 meter band	50.1 – 54.0	19.7 – 18.2	1,500	3	9
2 meter band	144.0 – 148.0	6.8 – 6.65	1,500	3	9
1 ¼ meter band	219 – 225.0	4.49 – 4.47	50 (peak envelope power)	3	9
70 centimeter band	420 - 450	2.34 – 2.19	1,500	3	9
33 centimeter band	902 - 928	1.09 – 1.06	1,500	3	9
23 centimeter band	1240 - 1300	0.79 – 0.76	1,500	3	9

Table 13

Radio Transmitting Services, (continued)

(Partial List)

Type of Service	**Frequency (Megahertz)**	**Wavelength (feet)**	**Maximum Transmitter Power (Watts)**	**Safe Distance Table for One Ohm Detonators**	**Safe Distance Table for 50 Ohm Detonators**
Transportation/Police/Gov't/Telecommunications					
VHF Fixed Station (Fire/Gov't/Business/Railroad)	150 - 174	6.56 – 5.66	500 (ERP)	3	9
VHF Mobile Station	158	6.23	60	3	9
UHF Mobile Station	450 – 455 & 460 - 465	2.19 – 2.12	500	3	9
UHF Mobile Station	450 – 455 & 460 - 465	2.19 – 2.12	60	3	9
Two-Way Communications					
Cellular Telephone Handset	824 - 849	1.19 – 1.16	3	3	9
Cellular Telephone Handset	869 - 984	1.13 – 1.10	3	3	9
Cellular Telephone Service Tower	800 - 900	1.23 – 1.09	500 (ERP)	3	9
HF Range Central Station	25 - 50	39 - 40	500	2	8
HF Mobile Unit	25 - 50	39 - 40	500	3	9
VHF Range Central Station	148 - 174	6.6 – 5.6	600	3	9
VHF Mobile Unit	148 - 174	6.6 – 5.6	180	3	9
UHF Range Central Station	450 - 470	2.2 – 2.1	1,500	3	9
UHF Mobile Unit Amateur	450 - 470	2.2 – 2.1	180	3	9
LF Range (Aviation)	0.2 – 0.4	5,000 – 2,500	2,000	1	7
HF Range (Aviation)	2.85 – 23.85 in select narrow bands	345 - 41	50,000	2	8
VHF Range (Aviation)	118.0 – 135.9	8.3 – 7.24	50	3	9
UHF Range (Aviation)	225 - 500	4.4 – 2.0	100	3	9
Radio Teletype (RTTY)	3.62 – 28.095	267 - 43	50,000	2	8
Microwave Relay	2,000 – 12,000	0.5 – 0.08	50	See Page 14	See Page 14

Table 13
Radio Transmitting Services, (continued)
(Partial List)

Type of Service	Frequency (Megahertz)	Wavelength (feet)	Maximum Transmitter Power (Watts)	Safe Distance Table for One Ohm Detonators	Safe Distance Table for 50 Ohm Detonators
Navigational Aids					
Radio Range Beacon ("A-N")	0.20 – 0.415	5,000 – 2,400	600	1	7
Loran-C	1.8 – 2.0	547 - 492	1,000,000 peak, 3000 avg.	6A	12A
VOR-ILS (Aviation)	108 - 118	9.1 – 8.34	200	3	9
Shoran	290 - 320	3.39 – 3.1	25,000 peak, 1,500 avg	6	12
Long-Range Radar (non-military)	1,300 – 1,350 (L-Band)	0.76 – 0.73	1,000,000 peak, 100,000 avg	See Page 31	See Page 38-39
10cm Radar (non-military)	2,700 – 2,900 (S-Band)	0.37 – 0.34	750,000 peak , 1,500 avg	6	12
Radar Transponder Beacon (RACON)	2,900 – 3,100 (S-Band)	0.32	0.6	6	12
Radar Transponder Beacon (RACON)	9,300 – 9,500 (X-Band)	0.104	0.6	6	12
3 cm Radar (non-military)	10,000 (X-Band)	0.1	50,000 peak	6	12
Loran-C	0.1	3,000	1, 500,000	6A	12A
VOR	110	8.95	100	6A	12A
Localizer	110	8.95	100	6A	12A
Glide Slope	315	3.12	15	6A	12A

(1) Maximum Effective Radiated Power (ERP)

(2) Maximum Effective Radiated Power (ERP) is 100,000 watts but some FM stations were "grandfathered" to as high as 320,000 watts

(3) Geographical power restrictions may apply.

Table 14
Table of Definitions

A number of these definitions have been abstracted from FCC regulations. Also, please refer to Federal Standard 1037C, dated 7 August 1996, for a more complete list of definitions and terms related to telecommunications.

Amateur Service

A service of intercommunications and technical investigations carried on by duly authorized persons interested in radio technique.

Amplitude Modulation (AM)

A form of RF transmission where the information contained in the signal varies the strength of the RF carrier.

Antenna

An electrical conductor or series of conductors configured to radiate or receive RF electromagnetic energy.

Antenna Gain

A characteristic of a directional antenna; the ratio of the RF field strength at a particular location in the direction of maximum radiation and that field intensity produced by an isotropic antenna operating at the same power input.

Aviation Services

Services of fixed and land stations, and mobile stations on land and on board aircraft "primarily for the safe expeditious and economical operation of aircraft."

Band

A group of RF frequencies bounded by an upper and a lower frequency limit generally dedicated to one type of radio transmission service.

Bluetooth

A wireless system utilizing frequency hopping spread spectrum technology which may connect a variety of devices such as personal computers, laptops, mobile phones, video game consoles, printers, cameras, etc., into a local area network. The systems operate in the 2.4 to 2.48 GHz band and a maximum power of 100 milliwatt.

Broadcasting Service

A radio communication service in which the transmissions are intended for direct reception by the general public.

Citizens Band Radio

A radio communication service of fixed, land, and mobile stations intended for personal or business radio communication, radio signaling, (and) control of remote objects or devices.

Double Sideband

A type of radio transmission characterized by a modulated carrier signal whose upper sideband is the sum of the carrier and the modulating frequencies and the lower sideband is the difference between the carrier and the modulating frequencies.

Fixed Service

"A service of radio communication between specified fixed points."

Fixed Station

A station in the fixed service.

Frequency Modulation (FM)

A form of radio transmission where the information contained in the signal varies the frequency of the RF carrier.

Glide Slope

Used as a portion of an aviation instrument landing system, (ILS), a Glide Slope station provides “up” and “down” steering data to aircraft on landing approach.

Global Positioning System

A system of orbiting satellites and sometimes fixed base stations used in conjunction with a receiver to accurately locate the receiver in three dimensional space.

Horizontal Polarization

A configuration where an electromagnetic wave has an electric field that is parallel to a reference plane such as the Earth’s surface.

International Broadcast Service

A service “whose transmissions are intended to be received directly by the general public in foreign countries.”

Isotropic Antenna

A hypothetical antenna characterized as a point source which radiates uniformly in all directions.

Land Station

A station in the mobile service not intended to be used while in motion.

Localizer

Used as a portion of an aviation instrument landing system, (ILS), an ILS localizer station provides “left” and “right” steering data to aircraft on landing approach.

Loran-C

Loran-C is a radio-navigational aid providing maritime position fixing capability. With the development of Global Positioning Systems, Loran-C in the U.S. was phased out as of 08 February 2010. U.S. participation in the Russian-American and Canadian Loran-C chains will temporarily continue supporting those international agreements.

Maritime Services

Services intended for maritime radio communication and including fixed stations, land stations, and mobile stations on land an on board ships.

Mobile Services

“A service of radio communication between mobile and land stations, or between mobile stations.”

Mobile Station

“A station in the mobile service intended to be used while in motion or during halts at unspecified points.”

“No-Fire” Power Level

The maximum “no-fire” power level is the maximum DC or RF power at which a blasting cap or detonator will not fire with a probability of .999 at a confidence level of 95 percent as determined by test and computer simulation.

PAVE PAWS

An acronym for “Precision Acquisition Vehicle Entry-Phased Array Warning System, a phased-array radar system operating between 420-450 MHz in pulsed mode with a power level per face of 577,000 watts. The purpose of the system is the detection of incoming sea-launched missiles and ICBMs.

RACON

A radar transponder beacon that is commonly used to mark maritime navigational hazards. They may be operated by the U.S. Coast Guard or the owners of offshore oil platforms. Most operate on the X band and S band marine radar bands.

Shoran

Used for short-range navigation; shoran consists of a pulse transmitter and receiver with two transponder beacons at fixed location.

Single Sideband Transmission

An amplitude modulated transmission where only one sideband of the central carrier frequency contains the information to be transmitted; generally used due to its ability to efficiently use the power of the transmitted carrier.

Spread Spectrum

A specified type of radio which intentionally spreads its transmissions across a specified band of frequencies so to reduce interference with and from transmitters operating in the same range of frequencies.

Standard Frequency Terms and Bands

1 Megahertz, MHz = 1,000,000 cycles per second
1 Gigahertz, GHz = 1,000,000,000 cycles per second
Medium Frequency Band – MF 0.3-3 MHz
High Frequency Band – HF 3-30 MHz
Very High Frequency Band – VHF 30-300 MHz
Ultra High Frequency Band – UHF 300-3,000 MHz
Extremely High Frequency (EHF) 30 – 300 Gigahertz

Transmitter

An electronic device used to generate an RF carrier signal, add the information to the carrier and deliver the energy to an antenna system for transmission.

Vertical Polarization

A configuration where an electromagnetic wave has an electric field that is perpendicular to a reference plane such as the Earth’s surface.

Watt

A unit of electrical power.

WiFi

A type of wireless local area network, (WLAN), system that enables a variety of devices such as personal computers, video game consoles, mobile phones, MP3 players, etc., to connect to the Internet. The FCC limit the equivalent isotropic radiated power, (EIRP), to 1 watt for frequency hopping systems operating in the 2.4 GHz to 2.483 GHz band employing 75 hopping channels or more.

Table 15

List of Safety Library Publications

The IME Safety Library is comprised of publications addressing a variety of subjects relating to safety. These publications are revised, as necessary, by staff and technical representatives of IME member companies. Currently, the Safety Library consists of the following publications:

SLP 1	Construction Guide for Storage Magazines (Sept 2006)
SLP 2	The American Table of Distances (June 1991-incorporates changes through October 2011)
SLP 3	Suggested Code of Regulations (October 2009)
SLP 4	Warning and Instructions for Consumers in Transporting, Storing, Handling and Using Explosive Materials (October 2009)
SLP 12	Glossary of Commercial Explosives Industry Terms (July 2010)
SLP 14	Handbook for the Transportation and Distribution of Explosive Materials (April 2007)
SLP 17	Safety in the Transportation, Storage, Handling and Use of Explosive Materials (October 2011)
SLP 20	Safety Guide for the Prevention of Radio Frequency Radiation Hazards in the Use of Commercial Electric Detonators (December 2011)
SLP 22	Recommendations for the Safe Transportation of Detonators in a Vehicle with Certain Other Explosive Materials (Feb 2007)
SLP 23	Recommendations for the Transportation of Explosives Division 1.5, Ammonium Nitrate Emulsions, Division 5.1, Combustible Liquids, Class 3, and Corrosives, Class 8 in Bulk Packagings (October 2011)
SLP 25	Explosives Manufacturing & Processing Guideline to Safety Training (May 2011)
SLP 27	Security in Manufacturing, Transportation, Storage and Use of Commercial Explosives (January 2005)
SLP 28	Recommendations for Accountability and Security of Bulk Explosives and Bulk Security Sensitive Materials (September 2007)
SLP-29	Recommendations for the Environmental Management of Commercial Explosives (March 2011)

For further details and information, or to order the IME Safety Library and Safety Publication, you may fax, mail, call, or place and order through the IME Web site at www.ime.org/ecommerce. The IME's safety library publications are also available in electronic form for downloading in Portable Document Format, (PDF) from the IME Web site.

Order via:

Phone:	1-202-429-9280
Fax:	1-202-293-2420
Address:	1120 19th St., N.W. Suite 310 Washington, D.C. 20036

Prepayment is required unless an account has been established with IME. VISA, MASTERCARD, and AMERICAN EXPRESS credit cards are accepted.

Table 16

List of IME Guidelines and Recommended Practices

In addition to the Safety Library Publication, IME has approved the following recommended practices for use within the industry. Further information on these guidelines and practices may be found on the IME Web site at www.ime.org.

1. Date/Plant/Shift Code
2. Shelf Life of Explosive Materials
3. Inert Production and Distribution Standard
4. Perchlorate White Paper
5. Best Blasting Practices
6. Guidelines for the Pumping of Bulk, Water-based Explosives
7. X-Ray Radiation Effects on Explosives

IMESAFR

Institute of Makers of Explosives

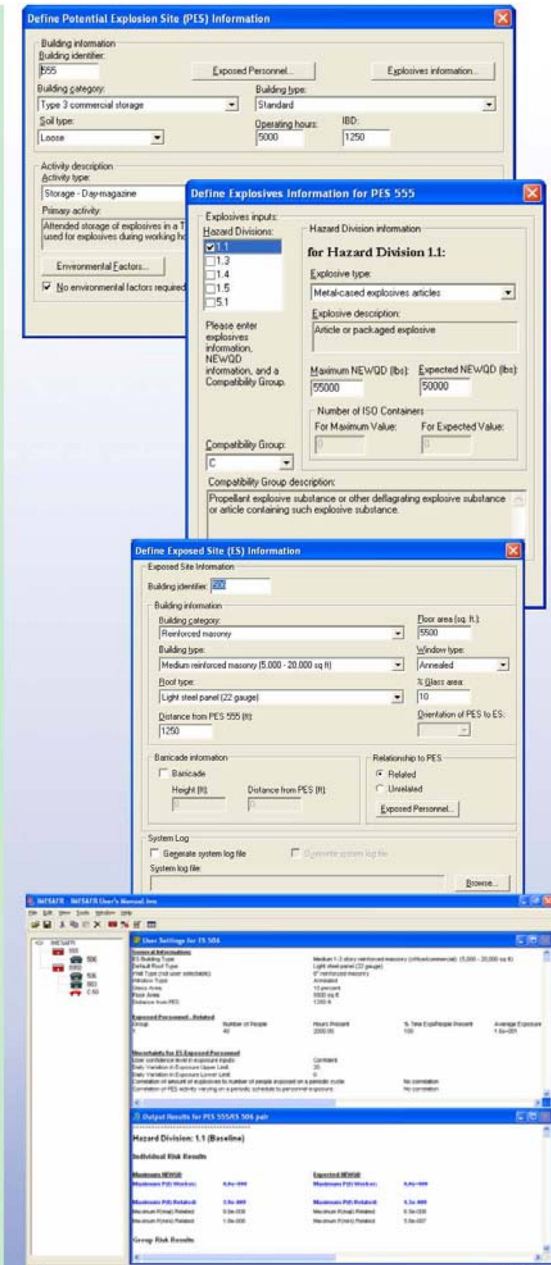
A-P-T Research, Inc.

What is IMESAFR?

Institute of Makers of Explosives Safety Analysis for Risk (IMESAFR) is a probabilistic risk assessment tool used to calculate risk to personnel from explosives facilities. This tool is a supplement to the longstanding American Table of Distances. Whereas the ATD provides a level of safety based on explosives quantity and distance, IMESAFR determines a level of safety based upon risk. In addition to explosives quantity and distance, IMESAFR uses the donor structure, the activity at the donor, and the structure of the exposed sites to determine the level of safety.

Why was IMESAFR developed?

IMESAFR was developed to provide a more comprehensive assessment of the overall risk of explosives operations. The commercial explosives industry in the United States uses the ATD as the basis for safe siting of explosives storage facilities. ATD siting involves the evaluation of a specific magazine and inhabited building or public highway, which are referred to as a Potential Explosion Site (PES) / Exposed Site (ES) pair in IMESAFR. This evaluation yields the recommended separation distance based on the quantity of explosives involved and whether a barricade exists. Although the same criteria can be applied to explosives manufacturing operations, the ATD was intended for use in limited permanent storage situations. In addition to permanent storage situations, IMESAFER accounts for other activities such as manufacturing, assembly, and loading and unloading.



What data is needed to run IMESAFR?

Since the IMESAFR model is menu-driven, the user must make judgments as to which menu item best fits the situation under analysis. These judgments require knowledge of the explosives and the building construction for the PES and ES, and the annual exposure of the personnel.

Who should use IMESAFR?

The IMESAFR model was designed to assess explosives risk by safety professionals. The individual should have some knowledge of the application of ATD principles, explosives Hazard Class/Divisions, explosives quantity, and information concerning the facilities and personnel surrounding the PES and the ES.

Cost: IME members: $600; Non-IME members: $1200

System Requirements

IMESAFR is fully compatible with Windows 2000, XP, 98, and NT operating systems.

Training

Training will be provided on a periodic basis at APT Research, Inc. in Huntsville, Alabama. Please check the APT website for the course schedule (www.apt-research.com).

Where can I get it?

IMESAFR was developed by the IME in conjunction with APT Research, Inc. Contact IME or APT for a copy.

A-P-T Research, Inc.

APT Research, Inc.
4950 Research Drive
Huntsville, AL 35805
www.apt-research.com

Institute of Makers of Explosives

The Institute of Makers of Explosives
1120 19th Street NW
Suite 310
Washington, DC 20036-3605
www.ime.org

DESTRUCTION OF COMMERCIAL EXPLOSIVE MATERIALS

At times it may be necessary to destroy commercial explosive materials. These may consist of explosives or blasting agents from containers that have been broken during transportation or may be materials that have exceeded their recommended shelf life or are believed to be overage or are no longer needed.

Due to the many developments in explosive technology over the past few years, the appearance and characteristics of products have undergone marked changes. To be sure that you are familiar with the properties of the product that you plan to destroy, the manufacturer of that product should be consulted for the most current product information and the recommended method of disposal and/or destruction.

The member companies of the Institute of Makers of Explosives have agreed to supply advice and assistance in destroying explosives. If the manufacturer is known, seek his assistance. If the manufacturer is not known, a member company of the Institute of Makers of Explosives may provide advice or assistance.

The above policy of IME member companies relates only to commercial explosive materials. It does not include handling improvised explosive devices or bombs, military ordnance, military explosives, or homemade explosive materials.

IME member companies also cannot become involved in destroying explosive materials, which have been used for illegal purposes, are reportedly stolen property or are considered as evidence in any potential civil litigation or criminal prosecution.

IME
institute of makers of explosives

1120 Nineteenth Street, N.W
Suite 310
Washington, DC 20036-3605
202/429-9280
Fax 202/293-2420

www.ime.org
info@ime.org

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