Reports of Premature Initiation of Electric Detonators by Radio Frequency Energy

compiled by

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PROVINCE OF QUEBEC
SEISMIC BLASTING ACCIDENT

***Note**: The following is a summary of the 22 page report plus 16 page appendix which was received from CSST (Commission de la Sante et de la Securite du Travail) of the Province of Quebec. The scientific laboratory report has been summarised and translated by Marcel J. Caron, Provincial Mining Specialist, Ministry of Labour, for the Province of Ontario, on July 23, 1993.

SUMMARY

Jean-Francois Lachance, 32, a blasting technician, employed by Geophysique Sigma Inc., was fatally injured when an explosion occurred at about 4:00 p.m. on November 9, 1991.

Mr. Lachance, a member of a three (3) man blasting crew, was preparing to load a charge for a seismic blast. The blasting was part of a study to determine soil conditions. This work was being done on a proposed waste disposal site in the municipality of Val-Des-Monts, North East of Hull in the Province of Quebec.

The probable cause of the accident, as reported in Quebec's Ministry of Public Security report, was attributed to the use of a portable radio in close proximity of an explosive.

Accident Summary

The crew consisted of three men; Duguay who dug the holes, Lachance who loaded the holes, and Rheault who initiated the blasting and operated the seismic unit. Verbal communication was achieved between the blasting crew and the instrumentation person with the use of a two way radio (Walkie-Talkie).

At about 4.00 p.m., Duguay was digging a hole which was about 1.5 feet deep with a shovel. Lachance informed Rheault over the radio that they were not ready to blast, but would be ready in about five minutes. Rheault, as usual, repeated the message to confirm he understood the message. Duguay had just completed the hole, and turned to ask Lachance if the hole was of sufficient depth, when the explosion occurred. Rheault, located more than 100 meters from the deceased, did not visually witness the explosion.

At the time of the accident the blasting line was not connected to the blasting machine and the electric blasting detonator leg wires were not connected to the blasting line. The damaged leg wires of the electric detonator (2.12 m), which were recovered after the accident, still had the manufacturers' uniting (short-circuited) wire. This wire must be removed in order to connect the detonator.

SUMMARY OF CAUSES

There were several hypotheses's as to what occurred, but the Quebec CSST inspector who investigated the accident concluded that there were two possibilities. These two were to be verified by the scientific police laboratory;

1. The charge was set off by the portable radio.
2. The charge was set off by the static electricity built up in the man's clothing.

LABORATORY FINDINGS

On June 11, 1993 Mr. Bernard Pominville, scientist, Fires and Explosives Branch, Division of Judicial Expertise, Ministry of Public Security of the Government of Quebec submitted his report on the probable cause of the accident, which caused the death of Mr. Jean-Francois Lachance.

Brief Review of Findings

Review of the photographs of the deceased injuries:

1. Major loss to left side of face.
2. Major loss to left side of neck.
3. Traumatic loss to left arm below the elbow.
4. Lacerations to the left shoulder.
5. Also observed: a) No injuries to right hand and arm.
   b) No injuries to legs except for a minor laceration.
   c) No injuries to the back.

The following observations were helpful in the determination of the possible causes and conclusion of the accident;

1. The detonation of the detonator alone would not cause such extensive injuries.

2. The deceased, standing, was holding the explosives in his left hand, the forearm bent and 90 degrees to the body e.g. almost horizontal.

3. The left hand which held the explosives was pointing to the left. The explosion occurred to the left of the deceased.

4. The right hand and arm were not near the charge.

5. The right hand was resting along the right side or behind the back.

Discussion

To understand what occurred, it is important to note that the possibility of the accidental detonation of the explosive, Forcite 75%, without the detonator, was rejected. There is always the possibility of the detonation of explosives containing nitro-glycerine, which have a relatively high sensitivity to a large number of forms of energy. However, the energy required to detonate dynamite explosives (Forcite 75%) is much greater than that required in the detonation of an electric detonator. For example, it requires 4×10^4 ergs. of energy to detonate an electric detonator but it requires 3×10^6 ergs. or, 100 times more energy to detonate nitro-glycerine explosives.

SUMMARY AND CONCLUSION

The deceased was fatally injured following the explosion of a small quantity of explosives which he held in his left hand. The explosives was primed with a detonator which was contained in the explosives or at the very least was in contact with the explosives.

The detonator was not connected to the blasting line or the blasting machine. The right hand was away from the explosive probably along his right side or behind his back. This position eliminates the possibility of rough handling of the detonator as the cause of the accident. This position infers that the detonator is already in the stick of explosives. To insert the detonator in the stick of powder, it is necessary to use both hands. Therefore, at the time of the explosion, the deceased was standing, holding the detonator and the explosive in his left hand.

Description of Equipment Used and Personnel;

1. Explosive: FORCITE 75% manufactured by ICI - 25 Kg. (7 Kg. used)
2. Detonator: Electric MASTERDET manufactured by ICI.
   250 E.B. Masterdet Instant 3 m (10 used)
   Note: (Both the Explosive and the detonator have not been specifically designed for seismic blasting)

3. Radio: Walkie-Talkie MOTOROLA, series HT600 FM, model ACH43SVU7120AN, serial number 651 PPU 2140 (used by deceased) and 651 PPS 5244 (used by the blaster). Normal Wattage of unit is 5W.
   The radio frequency is 165.030 MHz for either channel 1 or 2.

4. Blasting Crew:
   Jean-Francois Lachance, 32, Technician
   Guy Duguay, 21, blaster helper.
   Noel Rheault, Engineer, seismic blast initiator

Review two Main Hypotheses regarding the cause;

(Note: other hypotheses were reviewed by the Laboratory but dismissed as the cause.)

1. Static Electricity:

Static Electricity is produced by contact or separation of two different natural materials or temperatures. The static electric charges can be created and stored on the person by the movement of that person. Walking, rubbing objects together are examples of movements which can create static electrical charges. Static electricity can present a danger during a blasting operation if after its production and storage on the person or object it is released into an electric detonator.

Three conditions which are essential for static electricity to be a danger when using electric detonators are: 1. Production of static electricity, 2. Accumulation of the charge, 3. Liberation of the charge.

Potentials of 5000 V have been obtained during dry conditions. In some cases, energy of E = 3.75mJ has caused the detonation of certain sensitive detonators. These potentials of 5000 V are not that elevated. Potentials of 10 to 25 KV have been measured on humans.

The release of the charge from the human body, to be dangerous, must be released relatively close to the initiation point. A man charged with 5000 V can set off a detonator if the electricity is released to the leg wires of the detonator. To do this he must hold one end of the assembly while the other end of the detonator makes contact with the ground. A flow of electricity is therefore created. This hypotheses is not valid since the leg wires of the detonator assembly were short circuited. A second hypotheses is for the man to hold both leg wires, short-circuited, in his hand while the cap is permitted to touch the ground.

A current of electricity will flow if; the two conductors have a potential of 5000 V, the cap has a potential to ground, an arc of electricity is formed between the leg wires and the detonator or the leg wires and the explosives. The MASTERDET detonators are specially protected against these two methods of the discharging of static electricity. These detonators should not detonate when submitted to a discharge between detonator and the leg wires short-circuited from a condenser of 300 pF with a charge of 15KV. These facts are based on statistical information and are probable when using MASTERDET detonators. However, a MASTERDET detonator selected at random may produce slightly different result.

The production and storage of static electricity on a person, a human conductor, depends on the movement of the worker, and the clothing he is wearing at the time. The majority of the clothing worn by Mr. Lachance was partly or totally made of synthetic fibres, very resistant to the flow of electricity, however these fibres permit a very high production and accumulation of static electricity.

The weather, on the day of the accident, was sunny and cold which is favourable for the production of static electricity.

In summation, it is possible for this accident to have been caused by static electricity. The human body is capable of producing, storing, and releasing sufficient static electricity to cause a detonation.

Scenario- The deceased holds the charge in his left hand. The static electricity potential is produced by the worker's movements and stored on the person's body. The leg wires of the detonators (short-circuited) touch the ground. The static electricity travels along the casing of the detonator and down the leg wires to ground. An electric arc is produced between the casing and the bridge wire which caused the detonator to go off. This hypotheses must take into consideration that the MASTERDET detonators have a great resistance to this type of discharge of static electricity.

A detonator which has been subjected to physical damage, however could have its resistance reduced to static electricity.

2. Portable Radio:

Mr. Lachance was carrying a Walkie-Talkie unit on his belt. The FM unit produced 5 W at a frequency of 165.030 MHz.

A lot of studies were conducted in order to get to know the transmission characteristics of the radio, the reception (antenna) characteristics of the electric detonator and the transmitted energy and frequency of the radio. The radio involved in the accident was used in the tests. The explosion had caused some minor damages to the radio unit and it had to be repaired.

Fifty electric MASTERDET detonators were purchased. A simple method was used for the detonation. For safety precautions, the detonator cap was isolated in a blasting chamber. The detonators with 3 meter leg wires where extended and collapsed to form an antenna for radio reception. The radio, with recharged Ni Cad batteries, was activated to transmit in close proximity of the detonator or leg wires or in direct contact with the detonators or the leg wires. The geometry of the antenna was varied a number of times as well as the location of the transmitting radio. During the several days of trials, there was not

one detonation. The MASTERDET detonators tested were frequently replaced to prevent the desensitising of the detonation mechanism.

In summation, no detonations resulted from these tests using the 5 W radio whether near or in direct contact with the leg wires of the detonators.

Fifty detonator cap assemblies e.g. caps without the primary explosive or secondary explosive, were obtained to conduct additional laboratory tests. Instrumentation wires were welded to the detonation mechanism of the cap to measure its different electrical characteristics.

A 165.030 MHz signal was sent in the secondary detonation filament wire. The results indicated that the circuit was not completely resistant to the signal, and there appeared to exist, at a particular point, some resonances or drop in impedance which was of significant importance. Impedance of this wire is dependent, on the frequency, and the geometry of the conductors. By simply moving the conductors slightly it equally changed the point of resonance.

Secondly, voltage tests were conducted on the bridge wire. The voltages were found to be dependent on the position of radio transmission relative to the antenna formed by the detonator leg wires. The voltages varied greatly and this fact is of importance since the fluctuation can be predicted when the radio antenna is moved within the loop of the detonator conductors. Peak voltages (Vp-p) of 2.9 V were measured. Also mean voltages (Vrms) of 860 mV were measured. The energy dissipated in the circuit at the exterior of the resonance point was 18 mW. The energy dissipated in the circuit at the point of resonance was 73 mW. This later value approaches the critical value and is of such importance, that during the test, a detonation of the initiation system of the detonator occurred. This detonation occurred when the transmitter antenna was slowly moved within the loop formed by the conductors of the detonator.

COMMENTS

Two hypotheses remain the probable cause of the accident which caused the death of Mr. Jean-Francois Lachance.

The first is the creation, storage, and the discharge of the static electricity into the detonator. Although it is possible as a hypotheses, the scientist feels its not likely. The MASTERDET detonator is well protected against static electricity. Statistical information indicates, it will resist a discharge of 300 pF from a condenser with a charge of 15 KV.

The accident seems to have occurred at the moment the deceased was standing, holding the charge (detonator and explosives) in his left hand. If the conductors of the detonator are not touching the ground then there is no electrical flow. The conductors (leg wires) are thrown towards the ground to

unravel them and also to position the ends closer to the blasting cable. They could when making contact with the ground, cause the closure of an electric circuit and the flow of the accumulated charges.

The second hypotheses, is the use of a two way radio Walkie-Talkie) in the proximity of a detonator. The deceased is standing, holding the charge (detonator and explosives) in his left hand. The leg wires, slightly bent over each other, are released and the short-circuited ends fall to the ground. The deceased has a two way radio on his belt. Lachance for some reason or other wants to communicate with his partner Mr. M. Rhealt. He takes hold of the Walkie-Talkie in his right hand and moves it towards his mouth. The radio antenna touches the leg wires of the detonator. The deceased lowers his hand to release the antenna and inadvertently pushes on the radio's operation button and an explosion occurs. A second scenario, almost the same as the previous, assumes that the Walkie-Talkie is worn on the right hip (temporarily or not). Mr. Lachance lowers his right hand to communicate, to release or not, the radio from his belt and pushes the operation button.

RECOMMENDATIONS - (Division of Judicial Expertise)

A number of technical publications have been written which have studied the problems;

1. Safety guide for the prevention of radio frequency radiation hazards in the use of electric blasting caps. -IME Publication No. 20.

2. British Standard Guide to Prevention of inadvertent initiation of electro-explosive devices by radio frequency radiation.-BS 6657:1986.

3. Radio frequency-power sensitivity testing of detonator type 2M. Franklin Research Centre -TR P218.

The solutions are simple and always the same. The recommended safety distances are to be observed between the explosive charges or the blasting circuit and the transmission antenna.

REPORT – ONTARIO MINISTRY OF LABOUR

PREMATURE DETONATION OF AN ELECTRIC DETONATOR

INCIDENT

An electric detonator exploded prematurely in the cab of a truck on September 22, 1996 at Placer Dome's open pit operation near Timmins. One person suffered minor injuries and there was only minor damage. An explosives supplier had been contracted to load and fire the explosives for the blasting operations at this gold mine.

The shot-firer for the explosives supplier was in the process of running out the blasting line, and then was about to hook a detonator to the blast. He had anchored the lead wire to a stick at the start of the blast, then had rolled the spool to his dewatering truck, setting the spool in the back of the truck. He was carrying a portable radio that was turned on, when he received a radio call from a driller. He had the detonator in this hand and walked to his truck where he placed the detonator in the centre of the seat, next to a can of pop. He decided to talk to the driller from the truck, and set the radio next to his right hip. While starting the truck or releasing the clutch, the driller called again and this is when the detonator exploded. The shot-firer received a few pieces of shrapnel in his right arm and the pop can had a big hole blown into its side.

RESULTS OF THE INVESTIGATION

The shot-firer was carrying a 4 watt portable radio, with one channel at 466.7125 MHz UHF and the other at 467.5125 MHz UHF. The sending buttons on the radio and the remote speaker/microphone were examined after the accident and they did not display any sticking when depressed.

The dewatering truck was also equipped with a 10 watt mobile radio, operating with two channels at the same frequency as the portable radio. The sending button was examined after the accident and did not display any sticking when depressed.

The shot-firer stated that he did not transmit from either the hand held radio nor the mobile radio in the truck when the detonator exploded.

The detonator's legwires were still coiled within the manufacturer design specification with the banding paper in place. Leg wires were still shunted, with no sections of the wiring missing any insulation.

The exploded detonator was sent to the explosives company's laboratory for further examination. The laboratory determined that the static discharge protection was still intact, indicating that the detonator had not been subjected to a static discharge.

A part case of detonators from the batch being used was also examined. X-ray testing showed nothing abnormal about the internal components of the detonators. The average and all fire firing current for the lots of electric matches (the initiating device for the detonator) were well within specification. Twenty four of the returned detonators were tested first at 400 ma. and none of the units fired. These same units were then tested at 700 ma. and all of the units fired.

The hand held radio transmitter was tested with its antenna very close to or touching the folded detonator wires, and pick ups as high as 300 milliwatts were measured. This corresponds to over 500 ma. of current, a value which could cause the electric match to fire.

CONCLUSIONS AND RECOMMENDATIONS – extracts from the Explosives Supplier Report

1. The detonators were a normal product and did not contribute to this premature firing due to any defect.

2. If the portable radio was transmitting with its antenna very close to or touching the wires of the detonator, sufficient power could be picked up to cause the detonator to fire.

3. Although no testing was done on the mobile radio in the truck, it does represent another source of power close to the detonator.

4. Unless some other source of energy is identified which would have cause this premature initiation, RF (radio frequency) is the most likely explanation.

5. The Institute of Makers of Explosives booklet 20 on Radio Frequency continues to be the guideline for use with electric detonators in the vicinity of RF transmitters. Had it been followed, the detonator would have been kept a reasonable distance from both transmitters.

6. Consideration should be give to using another type of detonator which contains an electric match that requires a much higher firing current.

MINISTRY OF LABOUR COMMENTS

1. Immediately after this incident, the explosives supplier required that all transmitters be turned off or removed from a person when using detonators.

2. The pertinent mining regulation at the time of this accident was R.S. 154(2)(a), which stated that no radio frequency transmitter shall be used at a surface mine within twenty metres of a blasting operation.

3. This regulation was changed in August 1997 to read as follows:

154. (1) No electrical blasting circuit connections shall be made on or near to surface or in or near to a shaft during an electrical storm in the vicinity.

(2) If electrical blasting operations are undertaken, an employer shall ensure that the operations are conducted so as to ensure that there is no interference from any system, device or controller capable of producing radio frequencies or radiating electromagnetic energy.

(3) An employer shall ensure that a system, device or controller that is capable of producing radio frequencies or radiating electromagnetic energy does not set off detonators.

(4) Subsections (1), (2) and (3) do not apply with respect to blasting operations that use,

(a) a combination blast initiation device and high-frequency radio signal that have been designed for that purpose; or

(b) a high-frequency impulse-initiated detonator. O. Reg. 272/97, s.27.

4. The Ministry of Labour Mining Health & Safety Program has a Health & Safety Guideline R.S. 154 (2), (3) and (4) "Radio Frequencies and Blasting Caps" that addresses this subject. The Guideline makes reference to the document "Safety Guide for the Prevention of Radio Frequency Radiation Hazards in the use of Commercial Electric Detonators (Blasting Caps)" – Publication 20 – produced by the Institute of Makers of Explosives. In addition, an older CSA standard, Z-65-1966, "Radiation Hazards from Electronic Equipment" gives useful information on safe distances and testing specific radios.

5. Another Ministry Guideline, R.S. 151 "Stray Current Hazards Associated with Electric Blasting Caps" gives further information on other sources of accidental initiation of blasting caps, including lightning, static electricity, electrical stray current and electromagnetically induced currents.

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February 8, 1999

Premature Detonation of Explosives - January 19, 1999

Revised: August 31, 1999

Summary of Critical Accident

On January 19, 1999, a worker at Inco's Stobie Mine sustained injuries to the face, hands and chest when an electric detonator he was hooking up to two lines of detonating cord prematurely detonated. On the left hand he lost the tip of his thumb and on the next three fingers lost the ends to the first knuckle. The right hand was severely burned. The miner also sustained metal penetration about the hands and face. Another worker sustained a contusion injury to his lower leg from impact by flyrock. Two other workers were in the area at the time, but not in the path of the blast at the time of the accident.

The workers were preparing to blast oversize chunks when the accident occurred. A total of 19, 1 1/4" x 16" sticks of powder had been placed in one chamber and 13 sticks in another blasting chamber.

The leg wires of the electric detonator had been connected to a roll of 500 feet of duplex lead wire shorted together at the tail end of the reel. The blasting wire was supported by a piece of rope, near to the point of connection to the detonator leads. The co-worker holding the reel approximately 6-8 feet away from the electric detonator, was carrying a Motorola leaky feeder radio with the lapel push-to-talk microphone disconnected. This exposed the accessory connector pins on the side of the radio that may have come into contact with metal tools worn on his belt or the spool of duplex wire. This may have caused a "Man Down" signal to be inadvertently transmitted which induced sufficient energy to heat the bridge wire of the electric detonator to cause ignition.

All the explosives detonated injuring the worker hooking up the blast and the co-worker holding the coil of lead wire. This accident had the potential of fatally injuring both these workers.

Investigation

1.0 The detonator involved, was a Dyno Nobel America, "Electric Super SP 0" electric detonator.

2.0 Samples of electric detonators of three different manufacturing dates were taken from the mine and sent to the Natural Resources Canada, Canadian Explosives Research Laboratory for testing. Forty-four of the detonators were tested first at 350 ma and none of the units fired. Sixty-three of the units were tested at 500 ma and all units fired. The bridge wire resistance was tested on thirty detonators and varied from 1.69 - 2.07 ohms. The electrical characteristics were all within specifications declared by the manufacturer.

3.0 Measurements for stray currents showed a potential difference of 180 mVDC between the blasting wire and the screen and 245 mVDC between the floor and screen. Although the existence of stray currents could not be ruled out, the blasting circuit seems to have been well insulated from any ground currents.

4.0 Motorola radio transceivers, Model ITT-1000, 411.250-412.800 MHz, are used for communication throughout the mine. These radios are purposely programmed to limit transmission to only 1 watt, although the actual measured power of the radio used at the accident site was 1.28 watts. Detailed measurements found that it was not possible for the radio transmitting at 1.28 watts to cause the accident 8 feet from the electric detonator; even with the antenna touching the duplex wire. The radio had to be less than six inches from the electric detonator with the antenna touching or near the duplex wire for it to initiate the detonator.

5.0 The leaky feeder system at the accident site was not working at the time of the accident. The leaky feeder cable installed throughout the mine radiates 7 milliwatts to allow other radios to receive the transmission.

6.0 This model of radio has an emergency feature known as "Man Down", whereby the radio is capable of transmitting an emergency 0.5 second signal burst, automatically every 4 seconds at a power of 4.56 watts. Normally the feature is activated by depressing a push-button on the top of the radio. Motorola turned this off by programming the radio to ignore this feature. However it was discovered that this feature could be inadvertently activated if two of the contacts of the accessory connector were shorted for 5 seconds.

7.0 The accessory connector is used to attach a hand held push-to-talk microphone that can be clipped to the worker's lapel. At the time of the accident, the accessory microphone was detached and this accessory connector exposed. The accessory connector is on the front of the radio and consists of a double vertical row of flat, square, flush contacts with 7 contacts per row.

Probable Cause of Premature Detonation

It is believed that the probable cause of the accident was the shorting of the accessory connectors when they touched against a metal clip, tools on the miner's belt or with the metal duplex wire spool. This in turn activated a "Man Down" high energy signal burst of 4.56 watts. It was demonstrated that sufficient RF energy could be coupled into the electric detonator wires to heat the bridge wire to ignition with 4.56 watts of power only 8 feet away with the antenna touching or near the duplex wire.

Company Action

1.0 After the accident, the company checked all its' underground radios to ensure they transmitted at one watt, including the "Man Down" feature.

2.0 They also instituted a written policy on use of radios when handling electric detonators.

Hazard Alert

The Mines and Aggregates Safety and Health Association (www.masha.on.ca) has produced a hazard alert recommending the following:

- A worker involved in loading and blasting operations, or handling explosives materials should not carry or use any mobile radio transmitting device.
- Adequate signs should be placed to remind operators to turn off transmitters when near the blast site.
- Recommended safety distances must be maintained between the explosive charges or the blasting circuit and the transmission antenna. Review the specifications for the radio equipment used in your operation.
- All radios being used on-site should meet your company’s safety requirements.
- Workers should be advised of the hazards associated with electric detonators and radio frequencies.

Ministry of Labour Comments

1.0 A radio or other transmitter may inadvertently fire an electric detonator if conditions are right. Several accidents have been documented where electric detonators were inadvertently detonated by a transmitting radio. In all three cases the radio is believed to have been transmitting with its antenna very close or touching the electric detonator wires when it initiated firing. The leg wires were still shunted in all three cases.

- **September 1996: Ontario** - An electric detonator exploded in the cab of a truck causing minor injuries, when the driver carrying a 5 watt portable radio sat down in the cab. It is believed the sending button was accidentally pushed down and the antenna either came very close or made contact with the leg wires.
- **March 1995: Tasmania** - Eleven electric detonators exploded on top of the dash, five minutes after a 0.6 watt portable radio was placed on top of them. The driver and passenger received cuts, bruises and ear damage. The radio transmitted automatically in response to a locator system.
- **November 1981: Quebec** - A seismic exploration worker was fatally injured when the primed charge he was carrying detonated. The leg wires were found still short circuited. It is believed the antenna of the 5 watt portable radio was transmitting and either came very close or made contact with the leg wires.

Information Available:

- Health and Safety Guideline R.S. 154(2), (3) & (4), "*Radio Frequency and Blasting Caps*", August 11, 1997
- Health and Safety Guideline RS 151 "*Stray Current Hazards Associated with Electric Blasting Caps*", September 1984

2.0 The employer should institute safe work procedures to comply with section 154(3).

154(3) An employer shall ensure that a system, device or controller that is capable of producing radio frequencies or radiating electromagnetic energy does not set off detonators. ***(Regulations for Mines and Mining Plants - Ontario)***

3.0 Safe work practices have been developed for the work place parties to consider when complying with section 154(3). These are attached.

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