

Blasting Standard Operating Procedure

OP-M-499

Revision 2

Approved by [REDACTED]

Posting Date 6/11/07

*Active Divisions/Departments:
Area Directorate*

Table of Contents

Purpose	1
Scope/Applicability	1
Terms and Definitions	1
Responsibilities	6
Discussion	6
Blast Notification Procedures.....	6
Coordination with Firehouse	7
Other Coordination with Firehouse	8
Annual Report	9
Explosives Inventory- Access, Procedures and Directions.....	10
MAPCON Inventory	11
Explosives Orders.....	11
Explosives Storage and Loading Facilities.....	12
Blast Plans	12
Select Blasting Problems and Procedures.....	13
Sea Ice Hole Blasting	13
Introduction	13
Purpose of Blasting Holes in Sea Ice.....	14
General Technique.....	14
Description of a Completed Hole and Hole Maintenance	16
Factors Affecting Successful Hole Completion.....	17
Method for Blasting Sea Ice Holes.....	19
Variations in Method	21
Safety Factors	22
Environmental Factors.....	23
Town Blasting	24
Ground Vibration Precautions	24
Fly Rock Precautions.....	25
Pier Cable Removal Procedure.....	25
Separation Distances: McMurdo Area Radio Frequency Hazards	26
Appropriate Explosive Choice.....	27

Test Blasting.....	27
Explosives Destruction.....	28
References	28
Blasting Environmental Assessments.....	28
Environmental Assessment Memoranda	28
Review of Environmental Records.....	29
RPSC Safety Manual – Blasting Safety.....	29
IME Safety Library Publications.....	29
Code of Federal Regulations	29
State Licensing/ Permitting Requirements	30
Job Descriptions	30
Records.....	31
Attachments, Appendices	31
Appendix 1: Fleet Operations Report for Blasting	31

Purpose

The purpose of this procedure is to identify and explain the tasks and considerations necessary to perform safe, legal, and successful explosives storage and use in support of the United States Antarctic Program (USAP).

Scope/Applicability

This procedure applies to any person involved in the receipt, transport, storage, inventory, use, or destruction of explosives at McMurdo Station.

Terms and Definitions

Air Gapping

A method of reducing the ground vibration caused by an underground explosives detonation. The “air gap” is an expansion chamber created in the hole drilled for the explosive charge by leaving space between the charge and the stemming.

BATFE

Acronym for the United States Bureau of Alcohol, Tobacco, Firearms, and Explosives: a division of the U.S. Department of Justice.

Belay

A rock and mountain climbing term meaning to anchor or make fast.

BFC

Abbreviation for “Berg Field Center” (Building 160 at McMurdo Station): the facility that issues support equipment for remote field camps.

Blast Site

The location where an explosives detonation is planned or has occurred.

Burden

The distance in feet from an explosive charge, in the direction of relief, to the nearest free or open face.

Cap

Abbreviation for “Blasting Cap”: a device used to initiate an explosives detonation.

CFR

Abbreviation for Code of Federal Regulations. The CFR is the codification of the general and permanent rules published in the Federal Register by the executive departments and agencies of the United States Government.

Control Tower

The traffic control facility at an established airfield.

CRREL

Abbreviation for “Cold Regions Research and Engineering Laboratory”: a facility of the United States Army Corps of Engineers.

Dive Master

The individual who supervises an underwater diving operation.

DOJ

Abbreviation for the “Department of Justice”: a cabinet-level office in the United States Government headed by the U.S. Attorney General.

EA

Abbreviation for “Environmental Assessment”: a study done to determine potential effects that a proposed project or action will have upon the environment.

Ejecta

Term for material forcefully displaced in an explosives detonation.

“Fire in the Hole”

A warning exclamation used to indicate that an explosives detonation has been initiated. The McMurdo Blaster uses this exclamation at the end of the five-second countdown preceding detonation.

Fortress Rocks

A geological formation located in the foothills on the outskirts of McMurdo Station.

Fly Rock

Rock material forcefully displaced and sent hurling through the air by an explosives detonation.

Helo Ops

Abbreviation for “Helicopter Operations”: the office that schedules helicopter usage at McMurdo Station.

IME

Abbreviation for the “Institute of Manufacturers of Explosives”: a manufacturers’ trade group.

I-Net

Abbreviation for “Industrial Network”: the multi-purpose radio network that occupies VHF radio channel 1 at McMurdo Station.

Infosys

Abbreviation for “Information Systems” (also known as Information Technology-Communications or IT-Comms): the department that maintains communications equipment at McMurdo Station

Jamesway

A rigid-framed, canvas covered, portable, temporary building with a semi-circular cross-section.

Jiffy Drill

Brand name for a portable, hand-held, gasoline-powered ice drill.

kW

Abbreviation for “kilowatt”: a measure of energy.

Magazine

An approved facility for the storage of explosives.

Main Body

The Austral summer Antarctic construction season, beginning in early October and ending in late February.

MAPCON

Acronym for a computer software program used to track materials at McMurdo Station.

Milvan

A typical, commercial shipping container such as commonly seen on container ships. Also referred to as a “Conex Box.”

Misfire

The unsuccessful or incomplete detonation of an explosive charge.

MSHA

Abbreviation for the “Mine Safety and Health Administration”: a division of the United States Department of Labor.

NSF

Acronym for the United States National Science Foundation.

Off Belay

A mountaineering term indicating that an individual is no longer secured by a safety rope.

Permittee

For the purposes of this procedure, a person who has been issued a permit to use explosives, by the State of Colorado.

PETN

Abbreviation for *Pentaerythritol Tetranitrate*, (also known as *Penthrite*) one of the strongest known high explosives. It is used as the explosive core of detonation cord.

PI

Abbreviation for “Principal Investigator”: the lead scientist on an approved scientific project.

Red Label Area

A restricted access area established for the temporary storage of explosives or hazardous material.

RPSC

Abbreviation for “Raytheon Polar Services Company”: a business unit of Raytheon Company.

SAR

Acronym for “Search and Rescue.”

Scott Base Transition

The area adjacent to Scott Base where the road to Williams Field leaves the McMurdo Ice Shelf and proceeds onto Ross Island.

SCUBA

Acronym for “Self-Contained Underwater Breathing Apparatus.”

Shooting down

The process of causing an overhanging ice and snow cornice to collapse by detonating explosive charges in the snow field.

Shot

Common technical term for a planned explosives detonation.

Shot Time

The time an explosives detonation is scheduled to take place.

SIP

Acronym for “Support Information Package.” Following approval, this report consolidates all support requirements for a particular event.

Stemming

An inert material used to confine or separate explosives in a borehole.

Title 27 CFR, part 555

The portion of the United States Code of Federal Regulations that deals with the commercial purchase of explosives materials.

TNT

Abbreviation for “Trinitrotoluene”: an explosive compound.

Twin Craters

An area in the foothills above McMurdo Station, along the road to Arrival Heights. The name refers to two large depressions constructed by the U.S. Navy to serve as reservoirs during Operation Deep Freeze.

USAP

Acronym for the United States Antarctic Program: the umbrella agency under which all Antarctic activity sponsored by the United States National Science Foundation (NSF) is conducted.

Vod

Abbreviation for Velocity of detonation, a measure of the rate at which the

detonating wave travels through an explosive charge; the speed of detonation of a particular explosive.

Winter-Over

Term used to describe the period of the austral winter, or the personnel remaining in Antarctica for the austral winter.

Witness

The act of marking a spot by placing flags around it at a distance, such that the spot is centered between the flags. (For blasting purposes, the flags must be placed sufficiently distant that the blast does not displace them.)

Responsibilities

Blasting operations in and around McMurdo Station are directed by the Lead Blaster with oversight by the Fleet Operations Supervisor. Matters involving explosives handling, storage, and use are described in this procedure. This procedure assumes that the user of the document is a qualified, licensed blaster, and has been designated as such by Station Management.

Discussion

Blast Notification Procedures

The Blaster-in-Charge is required to publish a “Notice of Intent to Conduct Blasting Operations” 24 hours in advance of such operations whenever those operations are planned in and around McMurdo Station (including Scott Base, Ice Runway, Williams Field, Pegasus, and all roadways connecting them).

The Notice should include the following information:

1. Date of planned blasting operations,
2. Location of blasting operations,
3. Estimated shot time(s),
4. Affected buildings, areas,
5. Purpose of blasting operations,
6. Party or department originating the request for blasting services,
7. Any relevant restrictions (access or other) the Blaster-in-Charge may consider appropriate for the blast site before, during and after shot time,
8. An invitation to refer questions or comments to the Blaster, and the Blaster's phone number.

The notice is normally distributed by the e-mail system and originates with the Blaster-in-Charge.

The Blaster should be aware that many people have interest in knowing the time and location of blasting operations. These include not only other department heads who may have work scheduled in and around blasting sites, but also science groups involved in seismic monitoring, flight operations personnel, the McMurdo Fire Department, and many others. The Blaster-in-Charge should send out a "McMurdo All" notice with a carbon copy sent to the Scott Base Program Manager. A "McMurdo All" provides a broader scope of awareness of the use of explosives in an area at a designated time.

Note Notices of cancellation or postponements of planned blasting operations are similarly distributed through the e-mail system.

Coordination with Firehouse

When appropriate, the McMurdo Firehouse assists the Blaster with securing the blast area and guarding the shots.

On the day of blasting operations, the Blaster-in-Charge will warn the Firehouse, via radio communications with the Firehouse Dispatcher, on Channel 5, of shot times at 60-, 30-, 15-, 5- minutes before the blast. The

Blaster will then switch to the I-Net. The Blaster customarily also broadcasts a 5-second countdown to “Fire-in-the-Hole” on the I-Net.

On receiving the 30-minute pre-blast warning from the Blaster, the Firehouse will:

1. Broadcast an announcement of impending blasting via Radio Channels 1, 2, 3, 5 and 9,
2. Relay the notification to Scott Base via telephone, and
3. Mobilize Firehouse personnel in support of securing and guarding the blast area.

On receiving the 15- and 5-minute pre-blast warnings from the Blaster, the Firehouse will broadcast an announcement of impending blasting via Radio Channels 1, 2, 3, 5 and 9. Unless otherwise arranged between the Blaster-in-Charge and the Firehouse, the Firehouse support personnel will normally arrive at the blast site by the Blaster’s 15-minute warning. By the 5-minute warning, the Blaster and Firehouse personnel will have totally secured the blast area and established a firm no-entry zone. In an emergency, entry into or through the secured area can be arranged only through the concurrence of the Blaster-in-Charge with the Firehouse support personnel.

After blasting, the Blaster will inspect the blast site for misfires, unexploded materials, and other potentially dangerous conditions. When the Blaster is satisfied the area is secure, he notifies the Firehouse Dispatcher on Channel 5. The Firehouse, in turn, broadcasts a notice of cessation of blasting activity via the Radio Channels 1, 2, 3, 5 and 9, and security operations stand down.

Other Coordination with Firehouse

At the Blaster’s request, the McMurdo Firehouse and Crash Teams may be available to escort the Blaster in deliveries and transport of major explosive cargo. An example of when such escort assistance may be appropriate is on delivery of such cargo by plane at the Ice Runway, transport of the cargo through town, and final delivery of the cargo at the explosive storage facility. At such times, the Blaster will make specific arrangements with the Firehouse for the orderly movement of the cargo as the particular circumstance dictates.

Regardless of whether an escort is appropriate, the Blaster will notify the Firehouse prior to any significant explosive cargo movement in McMurdo and vicinity.

Annual Report

The Lead Blaster shall prepare an annual report, in MS Word® format, at the close of each Main Body season. The purpose of this report is to answer recurring questions, leave a record for future blasters, and fulfill BATFE requirements (see Title 27 CFR, part 555). Typically, the report is dated February 1st of each year. The report should include information from any Winter-Over blasting preceding the Main Body season for that year.

The annual report should be composed in three parts:

- Blasting Operations
- Explosives Consumption
- Year End Inventory

Blasting Operations should describe each blasting job undertaken: its purpose, location, the department originating the blasting service request, the results of blasting, and any findings meriting historical record. In addition, this part of the report should record any comments or recommendations for the improvement of future blasting operations.

Explosives Consumption should itemize the type and quantity (in pounds) of explosives used or disbursed from the magazines for each blasting project according to category (i.e. Science, Construction, Operations, Test Blasting, Explosives Destruction) and identify the project or event (i.e. JATO, S-007, etc.) This part of the report should also summarize the consumption by category.

Year-End Inventory should give the total explosives on hand at a fixed time each year. Typically, the inventory report has been dated February 1. The report lists the explosive contents of each of the five magazines at the McMurdo explosives storage site. The inventory is a balance of recorded take-outs and returns through the year, matched to a physical count of the contents. The “Year End Inventory” is required by federal regulation to be performed annually by the “permittee”—In this case, the Lead Blaster—by physical

count and by a record of transactions kept inside each magazine (Title 27 CFR, part 555). This record is required to be available for inspection by BATFE authorities for five years. It is a separate record from any MAPCON inventory record and is intended to be the permittee's record under his license. The "Year End Inventory" should include a note as to whether the Blaster's inventory is reconciled to the MAPCON inventory.

Explosives Inventory- Access, Procedures and Directions

In general, the Lead Blaster is the keeper of the keys to the explosives magazines. He is the only person authorized with unrestricted access to the magazines. In the event there is no Blaster on station for a period of time, such as during the Winter-Over season, the Lead Blaster should release the keys to the custody of the McMurdo Station Manager.

A record of take-outs and returns is kept in each magazine. In the course of recording daily transactions and performing physical counts, should the Lead Blaster discover any missing or unaccounted loss of explosives he should immediately notify the McMurdo Station Manager and prepare to notify authorities with the Bureau of Alcohol, Tobacco, Firearms, and Explosives. Missing explosives are a serious matter, and inventories are coming under closer scrutiny than ever with the proliferation of criminal mischief and terrorism.

In general, the McMurdo explosive storage magazines are intended for the storage of commercial high explosives. They are not intended for the storage of military explosives or hazardous chemicals. The Lead Blaster is responsible for ensuring that the contents of the individual magazines are compatible for storage. Furthermore, the Lead Blaster is required to be licensed under civilian regulations, but not by military regulations. Should the Blaster receive a request to admit military explosives into the magazines, he or she may fairly require the military explosives experts to show compatibility of their material with the commercial explosives prior to admitting them.

The NSF Safety Officer has given verbal direction to the Lead Blaster to minimize the explosive inventories in general. This direction derives in large part from a build-up of inventory due to heavy returns of unused seismic explosives from science projects.

Regarding this direction, note the following:

- Most of the seismic explosives and detonating cords have long shelf lives and do not pose a storage problem other than by their sheer quantity.
- The dynamites, however, have manufacturer's recommended shelf lives of 1 year, are by their nature subject to deterioration and can become dangerous. Managing an appropriate level of dynamite inventory is therefore critical.
- Blasting caps do not present a storage problem as they have long shelf lives and are of very low explosive weight. Maintaining a wide variety and large quantity of blasting caps permits the blaster to exercise flexibility in blast design and initiation systems.
- Devising acceptable substitutes from explosives inventories for explosives requested by grantees in their SIPs in general can reduce quantities.

MAPCON Inventory

The Lead Blaster should assist the Operations MAPCON Specialists in updating the MAPCON inventory. The MAPCON record, though it is not the legal record, is a valuable tool recording explosive specifications, procurement information, disbursements, and quantities on hand. Typically, once a month, the Lead Blaster might collect the magazine records and turn them over temporarily to the MAPCON Specialist for updating the MAPCON record.

Explosives Orders

All explosive procurements should be originated by the Lead Blaster, and no amendments or substitutions—particularly those from vendors—should be allowed except by his approval.

Explosives Storage and Loading Facilities

The McMurdo explosives storage facility is located at Twin Craters, on the hill above Fortress Rocks. It consists of five Type II storage magazines. All USAP explosives not in use or in transit are to be stored in these magazines.

On occasion, “Red Label Areas”—restricted access areas—associated with the various runways are used for the storage of explosives in transit to field camps. Specifications for the construction of Red Label Areas will be directed by the Airfield Manager, as directed by the USAP Air Operations Manual. The Blaster may enter the Red Label Areas, with the permission of the Control Tower, to inventory materials and to supervise cargo-handling personnel in the loading and unloading of explosives.

Occasionally, helicopters are used to transport explosives. At times, they use the Red Label Area for loading and unloading explosives packaged in cargo slings and nets to be carried underneath the helicopter. More recently, a flat area near the top of the explosives storage area (formerly occupied by a Navy Milvan) has been used. Using the flat area eliminates the need to transport explosives through town. Any loading and unloading should be done under the cooperative supervision of the Lead Blaster and the Helicopter Pilot.

Blast Plans

As often as appropriate, the Lead Blaster should develop a blasting plan prior to conducting drilling and blasting operations. The blast plan is a blasting design which graphically depicts the blast hole layout, the load factors and timing sequence for a given blasting operation. It can be to scale or otherwise, but it should show location references to nearby structures. In general, it serves as an orderly guide to blasting operations as well as a record to be followed by subsequent blasters. For a copy of the [Blasting Plan Form](#), please access this link. The form includes the following information.

- Date
- Shot time
- Location
- Purpose of Shot
- Number of Holes

- Hole Diameter
- Average depth of hole
- Number of Rows
- Space
- Burden
- Design Powder Factor
- Type of Powder
- Initiation Method
- Total Caps
- Depth per Hole
- Cubic Yards per Hole
- Powder (pounds) per Hole
- Powder Units (sticks) per Hole
- Total Powder (units and pounds)
- Estimated Cubic Yards to be Shot
- Shot Planned By: (name)
- Plan Checked By: (name)
- Comments/Results

Select Blasting Problems and Procedures

Sea Ice Hole Blasting

Introduction

RPSC blasters have developed techniques for opening holes in floating sea-ice where use of conventional drilling equipment is impractical. The blasting techniques have proven successful in sea-ice ranging from 8 to 15 feet thick.

For a [photograph of a completed dive hole](#), access this link.

The following discussion of blasting holes in sea-ice includes:

- Purpose of Blasting Holes in Sea Ice
- General Technique
- Description of Completed Hole and Hole Maintenance
- Factors Affecting Successful Hole Completion

- Method for Blasting Sea Ice Holes
- Variations in Method
- Safety Factors
- Environmental Factors

Purpose of Blasting Holes in Sea Ice

Blasting holes in sea ice offers a solution when the making of those holes is not practical by large mechanical augers. The blasting effort should be looked upon as construction work, and it is the end purpose of the hole that governs how the hole is to be blasted. The most common end purpose of the hole is to provide access for scuba divers and/or small submersible vehicles to the submarine environment. At the very least, this means the hole itself must be clear of floating ice bits, and the ice surface around the collar of the hole is clear and stable.

An alternative purpose for blasting holes in sea ice has been to raise large volumes of basal ice to the ice surface for scientific inspection and sampling of algal material. As blasting sea ice holes is essentially a crater blasting technique, the “stratigraphic inversion” principle applies here: on blasting, the deeper material in the hole is the last to come out of the hole. It eventually comes to rest on top of the first—or shallower—material out of the hole. For these purposes, not so much care is taken to preserve the integrity of the hole.

General Technique

Some of the technique for blasting these access holes derives from experiments and technical literature on blasting ice in arctic regions. In particular, one might consult CRREL Special Report (SR) 86-16 and CRREL Report (CR) 82-40 dealing with underwater explosions and blasting floating ice. These reports, however, deal with the most efficient use of explosives; that is, the maximum ice destruction for the least amount of explosives. The ultimate purpose of much of that testing and research was the destruction of ice islands, clearing sea lanes of floating ice, protecting offshore structures from impinging floating ice, and other such projects where maximum ice destruction for minimal explosives consumption is desirable. In other words, these blasting efforts represented demolition work. And all of the blast effects studied resulted from spherical charges:

L:D < 6:1,

(where: L=length of explosive column, D=charge diameter).

Blasting usable access holes in sea ice initially contemplates cylindrical charges (L:D > 6:1) which are not as energetically efficient as spherical charges. In general, blasting access holes involves two blasting stages: 1) an initial cratering and ice breaking shot, and 2) one or more subsequent clearing shots.

In the initial cratering shot, a pilot hole is drilled vertically through the entire thickness of floating sea ice. That hole gives the measure of not only the ice, but of the explosive column to be used. Explosive charges of diameter as close to and somewhat smaller than the hole diameter are then arranged end to end such that their length makes a column as long as the pilot hole is deep.

Additional charges are added to the column such that when the column is inserted into the pilot hole, and the top of the column is even with the collar of the hole, then approximately three feet of the explosive column extends below the bottom of the pilot hole. On detonation, the explosives within the ice fracture the ice to a radius proportional to the charge diameter, and to the hole diameter. The explosives suspended below the bottom of the hole create a large, elastic bubble of gas in the water below the ice.

With this first detonation, some of the ice near the surface is immediately ejected, not only from the near surface portion of the blast, but also from the initial expansion of the gas bubble. With the collapse of the bubble, and the attendant in-rush of water into the void, a larger volume of the broken ice is expelled or flushed from the hole. These two instances of ice ejection from one detonation are readily observable. Ejecta plume heights and shape are characteristic of charge weights and charge depths. At the conclusion of the initial cratering shot, the pilot hole is significantly enlarged, and this larger hole is full of water and shot ice chunks. A mound of shot ice forming a crater rim will often ring the ice surface around the enlarged hole.

If the blaster is lucky, a high surface wind will attend the blasting and carry the ejecta away from the hole before it falls back down into it. If that is not the case, the blaster must next clear the hole of the ice still in it. This is accomplished by placing a smaller charge shallowly (1' to 5' deep) into the ice rubble in the center of the enlarged hole. On detonation, the small charge blows some of the shot ice chunks directly to the side, out of the crater. It also

generates another bubble in the water, the collapse of which further expels shot ice from the hole. These clearing shots may be repeated as often as necessary to expel sufficient shot ice from the hole for end purposes, as with each clearing shot, the remaining shot ice in the hole is rafted higher with the rising column of water. The depth of the charge placement in these clearing shots affects the height of the mound formed at the crater rim—the deeper the clearing shot placement, the higher the rim.

Clearing shots have not been observed to break significant additional ice from the walls of the enlarged hole. At the conclusion of the clearing shots, some shot ice will remain floating near the surface of the hole. These ice bits can be scooped out of the hole using dip nets, or allowed to re-freeze with the water surface (as is often desirable).

Description of a Completed Hole and Hole Maintenance

A completed access hole will generally consist of a “throat” (the enlarged hole) of sufficient diameter to allow two divers to ascend side by side. This is desirable for divers, who for safety reasons, prefer to use a buddy system. By comparison, the maximum hole diameter achievable by mechanical augers available at McMurdo is 4 feet, and does not permit paired, side by side ascents. (The maximum hole diameter achievable by hole melters has not been given.)

Very often, the hole diameter at the bottom of the throat will be larger than at the top, producing a “belled” shape in cross section. Thought to be a result of the additional charges suspended below the ice, this is also a desirable shape for divers’ safety. Further, the shape provides some mechanical advantage for expelling shot ice from the hole with the bubble effects.

The top 1 to 2 feet of the access hole is generally about twice as wide as the throat. Thus, the entire shape of the completed hole in cross-section resembles an inverted wineglass: the top of the hole as the pedestal of the glass, the throat as the stem, and the belled bottom as the cup.

During extremely cold water and ice periods, the surface skim of ice remaining in the hole after clearing may be allowed to freeze in with the water at the surface of the hole. Under the best of circumstances, this can take up to half a day. When that new ice has formed to sufficiently support the weight of a man or men, a new, shaped hole may be cut in the new ice with saws.

Insulated hatch covers can be fitted into the shaped hole to prevent the hole from completely refreezing over and to maintain the shape of the hole. The best times for taking advantage of refreezing in the south McMurdo Sound are late September and October.

During warmer water and ice periods, refreezing does not readily take place. All the floating shot ice then will have to be removed from the hole to provide for maximum diver safety.

Factors Affecting Successful Hole Completion

Two important factors affect successful hole completion:

1. Selection of available explosives, and
2. Physical properties of the sea ice.

Available Explosives:

Over the years, RPSC blasters have experimented with various types of explosives, combination of explosives, and initiation systems and have perfected the techniques for producing access holes described above. In this, the explosive type of choice is dynamite. Moreover, of the dynamites available in the McMurdo magazines, large diameter Powerfrac™ (2 ½” and 3” diameter x 16” long) work the best. This is a fast-burning dynamite (vod= 18,000 fps) that was purchased for quarry work, not for sea ice blasting. Slower dynamite might serve better. However, these sticks strung together end to end with 50 grain detonating cord and top primed with an electric blasting cap can—under the best ice conditions—open a six- to eight-foot diameter throat in the initial cratering shot.

The proper match of pilot hole diameter to charge diameter is also problematic. All of the access holes blasted to date begin with a pilot hole drilled by a “Jiffy Drill”. While the auger strings are 4” diameter flights, the cutting bit is 5” diameter. Thus, the pilot hole is 5” diameter. Loading the pilot hole with 2- ½” diameter Powerfrac™ makes for a decoupled blast effect on detonation. Even though the seawater which rises through the pilot hole acts as efficient stemming, the decoupling of the explosive charge with the bore hole wall may not achieve the most efficient ice breaking radius for the charge. A 3” diameter pilot hole may give a better breaking radius with a 2-½”

charge. RPSC blasters have acquired a set of 3” augers and bits at McMurdo but these have yet to be tested for blasting sea ice holes.

Physical Properties of Sea Ice:

Furthermore, the colder and drier the sea ice, the more brittle its response to blasting, and the more efficient the use of explosives required to open a usable access hole in it.

Period 1 Ice, as it is called in the southern McMurdo Sound area, is the coldest and driest sea ice through the year. Period 1 Ice conditions run from September to late October. An initial cratering shot loaded as described above, using Powerfrac™, and fired in Period 1 Ice might open a “throat” from six to eight feet in diameter. Period 1 Ice conditions also promote refreezing effects over as short as a half-day’s time.

Period 2 Ice, from late October to mid November, will permit a somewhat smaller but still usable hole to be blasted as described above, but the refreezing effects may take days to form, if indeed they form at all.

Period 3 Ice, from mid November to mid December, will not permit a usable hole to be blasted as described above, and certainly no refreezing effects will form. As an example, an access hole was shot at New Harbor in December using the methods described above in FY 96-97, and the resulting throat was only 2’ to 3’ in diameter – unusable. The Period 3 Ice was simply too soft, warm, and wet and had a plastic rather than brittle response to the blast. Even the drill cuttings from the pilot hole came out as liquid, rather than as dry shavings. As an access hole was nevertheless needed, the remedy called for a 5-spot drilling pattern. With the outside of the box measuring 6’ to a side, loading each of the corner holes as it were a lone hole, leaving the center hole open as a “dead” hole, and then simultaneously firing the loaded holes. The resulting “throat” was a usable 8’ diameter access hole, but cost over 200-pounds of explosives for the cratering shot. That is roughly 4 to 5 times the amount of explosives required to open a hole in Period 1 Ice. Given the excessive explosive requirement for such a hole in Period 3 Ice, and the resulting increased environmental impacts, **blasters might seriously consider opening holes that will be needed in December during Period 1 or 2 conditions earlier in the year.**

Method for Blasting Sea Ice Holes

Once the sites for blasting sea ice holes have been selected by the Principal Investigator (PI), the pilot hole needs to be drilled at that site (that is, if it has not already been drilled and the hole sounded as part of the site selection process). The blaster is wise to first mark the collar point of the hole with two pairs of flags planted in “X” fashion, standing off at least 50’ from the collar point. Each pair, with one flag each on opposite sides of the collar point, then “lines” on the pilot hole. The lines from the two pairs then “cross” over the center of the pilot hole. Witnessing the pilot hole this way facilitates finding the center of the blast hole when it is otherwise buried in shot ice.

Before drilling the pilot hole, the initial charge should be prepared so that it can be quickly inserted into the hole before the hole refreezes. (Under certain ice temperature conditions, and with an abundance of under-ice platelets rising into the pilot hole, refreezing can begin in a matter of minutes.) An efficient method of charge preparation—which also allows for adjustment once the ice thickness has been determined—is as follows: 1) Pre-punch a number of sticks of Powerfrac™ by inserting the punch in the center of the end of the stick and angling the hole to come out the side of the stick. Do this on both ends of each stick. 2) Lace the column of sticks together, as if they were beads on a string, with 50 grain detonating cord, knotting the bottom stick to the string to act as a “stop”, adding enough sticks to the string to form a long enough explosive column as might be expected, and leaving about a 10’ leader of detonating cord at the top.

Drill the pilot hole. On holing through the ice, “pump” the drill string through the hole to flush it clear of drill cuttings and bottom platelet ice. In completing the pilot hole, note the height at which seawater rises through the hole. If water rises to the level of the collar or above it, an access hole at that location may not be practical.

With the depth of the hole—hence ice thickness—thus determined, add or subtract charges to the detonating cord string such that the entire column when inserted into the hole will extend about 3’ below the ice and the top of the column will sit 1’ to 2’ below the collar. Tie the detonating cord leader at the top of the column to a short stick of bamboo (about 2’ long) by which to suspend the explosive column from the collar of the pilot hole. Insert the string of charges into the pilot hole.

Attach an electric blasting cap to the remainder of the detonating cord leader, and fire the shot.

Depending on specific conditions, the result of this initial cratering shot will be either a well-formed crater with a mounded ejecta rim ringing the hole, or a crown of mounded ejecta over the top of the hole. In any event, the next steps are to clear the floating ice bits out of the hole.

Presumably, Powerfrac™ and electric blasting caps are on hand, as they had been selected for making the initial cratering shot. A two- or three-stick bomb of Powerfrac™, primed with a single blasting cap, makes an adequate bomb for clearing shots. To hold the sticks together before the shot, the following procedure works well:

Prepunch each stick by inserting the punch on the side of the stick, approximately ¼ of the way from the end, and working it straight through to the opposite side. Do this at both ends of each stick. Lace detonator cord through the top hole of each stick, and then through the bottom holes. Knot the end of the detonator cord to hold it in place and pull the slack out to of the bundle. Then, twist the detonator cord to form a half-hitch knot, slip the knot over the end of the bundle, and pull it snug. Make a second, similar half-hitch and snug it around the opposite end of the bundle.

In clearing shots, place the bomb in the center of the hole, among the bits of floating ice. (The “witness” flags described earlier will help the blaster find the center of the hole when it is obscured by ice.) The depth at which the bomb is placed will affect the shape and height of the mounded ejecta rim surrounding the hole. To keep the bomb from sinking below the desired depth, loop the detonator cord around one of the larger chunks of ice ejected by the first shot, then attach the blasting cap. A deeper bomb will produce a high, stacked mound, while a shallower bomb will produce a low, spread out mound. For an access hole intended to be left out in the open, the high, stacked mound provides a measure of windbreak for the divers. For an access hole intended to be covered by a tent or Jamesway, the low, spread out mound relieves construction hands of excessive shoveling work. Clearing shots are repeated until sufficient floating ice is expelled from the hole for its end purposes. Typically, 2 to 3 clearing shots are required. Any remaining floating ice may be cleared by hand, using dip nets and ice breaking bars. Very often the blaster’s duties are concluded after the last clearing shot has been fired.

Charge requirements for a typical access hole in 12' thick, Period 1 ice might be as follows:

- Initial clearing shot: explosive column 15' long, 11 sticks of Powerfrac™ (2 ½" x 16", @ 4 lbs per stick), total load = 44 pounds.
- Clearing shots: each at 2 sticks per bomb (8 pounds), three shots totaling 24 pounds.
- Total explosives consumed = 68 pounds per hole

Following each shot, the blaster should collect for trash the lead wires to the spent blasting caps.

Variations in Method

Over the years, RPSC blasters have experimented with various techniques of blasting sea ice holes as their assignments have permitted. Two successful variations in methods are discussed here:

1. Blasting twin holes simultaneously, and
2. Use of 3" diameter Powerfrac™.

Twin Holes

On occasion, two access holes spaced fairly close together may be requested by the PI. An example might be when an 8-section Jamesway is planned to be built over two access holes, each access hole positioned at opposite corners of the structure, or approximately 30' apart on center. Testing during the 94-95 season at New Harbor showed that two access holes could be shot simultaneously from pilot holes precisely collared at 30' on center, resulting in no significant intra-crater blast enhancement effects. The test took place on October 23, 1994, and the ice thicknesses were 9'10" and 10'0". The test produced two usable access holes.

When rather exacting specifications such as those above are called for, twin holes can and should be drilled on a precise measure and shot simultaneously. The blaster would do well to witness the pilot hole locations with flagging prior to shooting.

3" Diameter Powerfrac™

Up to the 96-97 season, the best available explosive on site for making sea ice holes was 2 ½" diameter x 16" Powerfrac™ which weighs 4 pounds per stick.

For the 96-97 season, the blasters obtained a small quantity of 3" diameter x16" Powerfrac™ which weighs 5 pounds per stick. Only two access holes were required for the New Harbor diving that season, and the blasters used that opportunity to compare the performance of the 3" sticks to the 2 ½" sticks. The test took place in late October in ice from 12' to 13' thick. The 2 ½" diameter charges used in one hole produced a roughly 6' diameter throat. The 3" diameter charges used for the other hole produced a roughly 8' diameter throat. Both holes were perfectly usable access holes. It was apparent that the 25% extra charge weight with the larger sticks gave a larger throat, which may be desirable for some end purposes.

Safety Factors

The Blaster-in-Charge should ensure that all personnel and critical property are withdrawn to a safe standoff distance when blasting to avoid injury from fly-ice. Depending on the charge load, the safe standoff radius could be 500 feet or more. This standoff radius also applies to helicopters that frequently fly over areas where sea ice blasting operations are being conducted. Their pilots often enjoy watching the blasting while airborne, but they do not routinely contact the blaster. The blaster should warn the pilots of impending blasts when they are in the area by maintaining communications with them on Helo-Ops frequencies. As water and ice plumes reach fairly high with each shot, and wild fly-ice can reach significantly higher and farther, the blaster should refrain from firing the shot until the helicopters are well back of the standoff distance he has established..

Important: the Blaster-in-Charge should also ensure that there are no divers in the water anywhere near the area when sea ice blasting is in operation.

The Dive Master or PI will generally indicate the position for a secondary escape hole for divers where appropriate.

The blaster should remind divers entering an access hole of the possibility of blocks of shot ice trapped beneath the ice surface. The activity of divers under water could cause one of these blocks to drift into the throat of the access hole, which in turn poses a safety problem for the divers.

Environmental Factors

Blasters will not conduct sea ice access hole blasting operations (submarine blasting) where marine biota are observed within 1 kilometer of the blasting site. However, blasting surficial sea ice, such as blasting surface passages through pressure ridges, may proceed.

The methods of charge preparation described above are recommended as they contribute zero blast debris to the submarine environment, and nearly zero to the surface. Formerly, charges were prepared after the pilot hole was holed through. Often, the time between the pilot hole completion and the charge preparation was sufficient for the pilot hole to begin re-freezing. In view of that, the charges were formerly attached to long sections of bamboo (10' lengths, perhaps two lengths bound together). When inserting the column into the pilot hole, the bamboo acted as a ramrod assisting in forcing the charge column through the new ice in the pilot hole. On firing the shot, very often bamboo shards, bits of tape, and bits of wire from bottom primed charges wound up as trash on the sea floor and on the surface. Furthermore, long leaders of detonating cord across the ice surface—from an even earlier method of firing—left long tracks of black PETN residues on the ice surface. The recommended method of charge preparation, with short leaders and top priming, have reduced the solid blast debris to nearly zero.

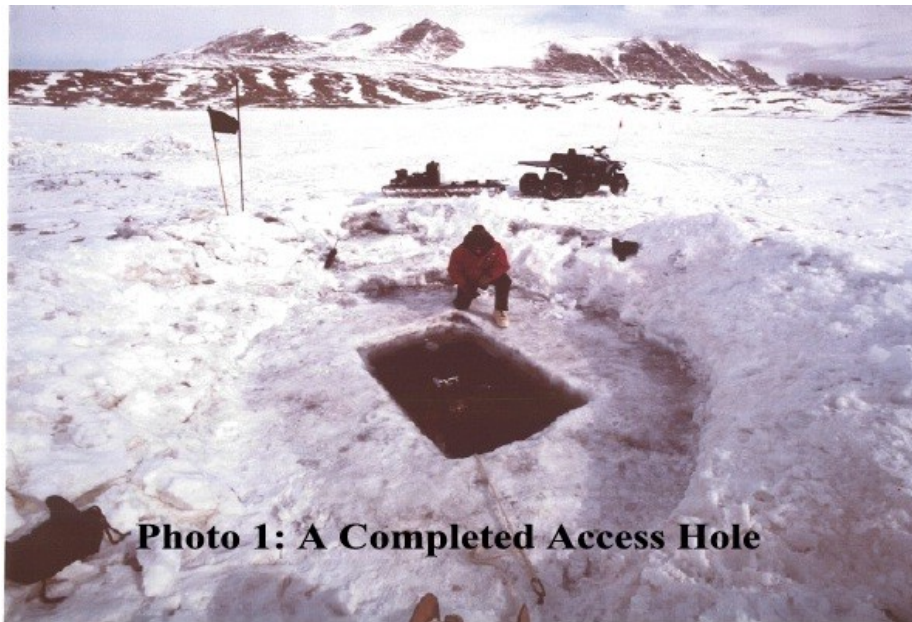


Photo by Jim Mastro

Town Blasting

Ground Vibration Precautions

When blasting operations are conducted near buildings and other structures, the blaster shall include an analysis of projected ground vibration effects in his blast plan.

Ground vibration effects are predicted by the equation (developed by the Office of Surface Mining, US Bureau of Mines, 1983):

$$W = (D / D_s)^2$$

Where: W = Charge weight (in pounds) per delay of 8 milliseconds

D = Distance (in feet) to nearest building

D_s = Scale distance factor

The scale distance factor is a dimensionless number. When the factor is set to correspond with a “maximum allowable peak particle velocity (V_{max} in inches per second)” for ground vibration, minimal structural damage can be assured by application of the formula. Applicable scale distance factors are given in the following table:

Distance from Blast	V _{max}	Scale Distance Factor
0 to 300 feet	1.25	50
301 to 5,000 feet	1.00	55
5,001 and beyond	0.75	65

For example, consider a shot planned for 50 feet away from a building. The formula indicates that the maximum charge weight per 8-millisecond delay that gives the maximum allowable peak particle velocity is 1 pound.

If a particular blast design requires charge weights in excess of those calculated maximums, the blaster can not guarantee zero structural damage due to ground vibration. In that event, he should seek the Station Manager’s approval before proceeding with blasting operations.

Fly Rock Precautions

Blasting stony ground near structures creates the potential for damage to those structures by fly rock. The Blaster can minimize that potential by:

- “Sweeping” the blast site free of loose rocks prior to drilling. Front-end loaders or light bulldozers normally do “Sweeping”.
- Using blasting mats, or
- Adjusting powder factors. Powder factors of .31- to .45 pounds per cubic yard have been reasonably effective in breaking ground in McMurdo. A factor of .50 pounds per cubic yard is more effective. If a blast design is somehow constrained to use low powder factors, air-gapping the blast holes can enhance rock breaking.

Pier Cable Removal Procedure

Over time, the moat separating the Pier from the Wharf will widen as the ice freezes. When this happens, the cables used to hold the Pier near the Wharf will tighten. This is not always avoidable and the tension on the cables can become extreme, increasing the potential for injury during removal of the cables. The following procedure should be followed to ensure that injuries do not occur:

If tension on the cable appears tight or if there is no slack (i.e. you are unable to lift the cable with your hands and release slack in the cable) explosive charges will be used to separate the cable.

The Lead Blaster will evaluate any cable requiring removal with explosives and the appropriate charge will be used for separation.

The charge should be placed in a way to minimize waste of the cable. The charge should be set within the loop on one end of the bollard and the remaining cable used as a shortened length.

Only one cable per bollard shall be severed at a time. If a more than one cable requires blasting, an all-day blasting event should be considered.

If there is a need for multiple shots and an all day blasting event is required: POCs from McMurdo and Scott Base shall be notified three days prior to the planned event.

The normal 24-hour Intention to Blast notice will follow.

Separation Distances: McMurdo Area Radio Frequency Hazards

A review of the Institute of Makers of Explosives Safety Publication #20 *Safety Guide for the Prevention of Radio Frequency Hazards in the Use of Commercial Electric Detonators*, and informal consultation with Mr. Greg Falxa, Communications Technician with RPSC Information Technology gave the following guidelines for separation distances of electric blasting caps from local sources of radio transmissions (January 7, 1995):

Radio Source	Antenna Location	Separation Distance	Reference
McM Hand Held Sets	n/a	20 feet	Table 3
McM Mobile Sets	n/a	70 to 100	Table 3
Remote Field Sets ²	n/a	800 feet	Table 2
MARS Station	Near Ob Hill Rd	1,700 to 2,500 feet	Table 2
T-Site ³	T-Site	2,500 to >5,500 feet	Table 2
T-Site VHF Stns	T-Site	100 feet	Table 3
Crater Hill	Crater Hill	100 feet	Table 3
McM FM Radio & TV	Bldg 155	800 feet	Table 4
B.I. Microwave	Next to BFC	N/A	Page 2
Shipboard Radar	Ships at dock	300 feet	Table 6

2 South Pole and certain field camps run higher transmit power. Consult with IS Technicians prior to operations at these locations.

3 T-Site's normal output is 1 kilowatt per transmitter in use, but it can go up to 5- to 10 kilowatts on command.

This compilation is intended for blaster's use as a safety guide for blasting operations and planning. It is not complete, for it has yet to take into account the many sources of radio transmissions associated with runway operations and air traffic control. The blaster should consult with RPSC Communications specialists regarding any new communications facilities before blasting operations.

At first glance, it appears that T-Site transmissions have the potential at maximum output power to encompass the McMurdo cap magazine within the recommended separation distance (i.e. greater than 5,500 ft.). The separation distance for normal output power of 1 kW would not likely capture the cap magazine.

The blaster should be aware of the content of Institute of Makers of Explosives (IME) Safety Library Publication #20. The greatest risk of radio frequency hazard exists when electric blasting caps are arrayed in a blast pattern, wire connections made, and the entire string acts as a receiving antenna. That risk is not present when the caps are shunted and the wires are wrapped in their packaged condition. Even under a greatest risk configuration, according to the IME publication, the possibility of unintended detonation from radio frequency hazard is remote to extremely remote.

Appropriate Explosive Choice

Explosives containing TNT, PETN, or similar products giving a negative oxygen balance reaction leave large quantities of black, carbonaceous blast residues. Those residues can be detrimental to the maintenance of groomed snow and ice surfaces such as runways and snow roads. Products of this type in the McMurdo magazines include detonating cord and boosters.

Dynamites offer a more oxygen-balanced reaction, minimizing dark blast residues. Use of dynamites should be considered when blasting operations are planned near groomed snow and ice surfaces. Examples of such activities might be blasting to free the Test Cart out of the ice at Pegasus Field, blasting in connection with South Pole Station construction, or collapsing crevasse bridges along traverse routes.

Test Blasting

Test blasting is permitted by an environmental assessment memorandum (see environmental documentation references below). The object of test blasting is two-fold:

- To test alternate explosive products and evaluate their performance in Antarctic environments, and
- To test blasting methods prior to conducting blasting operations.

The Blaster should record the results and findings of any test blasting in his year-end report.

Explosives Destruction

Through the year the Blaster sets aside dated, unreliable, and deteriorated explosives to be destroyed in a destruction event by detonation. The destruction event(s) traditionally take place toward the end of the Main Body season on the Ross Ice Shelf at a location off of the snow road between Williams Field and Pegasus Field.

Special Procedures for Notification of intent to conduct an explosives destruction event are given in the EA titled: *Management of Unreliable and Unsafe Explosives in Antarctica*.

In a destruction event, the Blaster should generally direct the blast downward, and take precautions to avoid launching missiles of solids and/or unexploded materials.

Following a destruction event, the Blaster should record details of explosive type and quantities (in pounds) destroyed, crater dimensions, and radius of ejecta. This data provides guidance for safe stand off distances for future destruction operations, and can be found in past annual blasting reports.

References

Blasting Environmental Assessments

Several NSF environmental documents have been written to cover blasting activity. These documents are available through the RPSC Environmental Office, and include:

Environmental Assessment Memoranda

Continued use and Evaluation of Explosives to Support Scientific Research in Antarctica, (No NSF file #), which covers all blasting activity including test blasting;

Management of Unreliable and Unsafe Explosives in Antarctica, (No NSF File #), which covers the destruction explosives;

Removal of Ice Cornice Safety Hazard, McMurdo Station, Antarctica;
(No NSF File #), which covers cornice blasting along the Scott Base
transition;

Review of Environmental Records

Using Explosives at Williams Field to Dislodge Ice Imbedded Structures,
(NSF File #PGAN9602.RO1); and

Use of Explosives to Dislodge Ice Imbedded Arches at South Pole, (NSF
File #SPST9800.RO1.

The Lead Blaster should familiarize himself with these documents.

RPSC Safety Manual – Blasting Safety

Further information may be obtained by referencing the RPSC Safety Manual.

IME Safety Library Publications

The IME, 1120 Nineteenth Street, NW, Suite 310, Washington, DC 20036-3605, and telephone: (202) 429-9280, has been an important resource to RPSC Blasters. It has furnished back-up documentation on arcane explosives issues such as criteria for recognition and disposal of deteriorated explosives, and historical studies on sympathetic detonation distances. In addition, the IME has published a series of pamphlets titled “Safety Library”. A complete set of these publications is located in the RPSC Denver HQ in the McMurdo Operations stacks, as well as in McMurdo in the Blaster’s office stacks.

Code of Federal Regulations

Title 27 of the Code of Federal Regulations of the Bureau of Alcohol, Tobacco, Firearms and Explosives, Department of Justice, Part 555 “*Commerce in Explosives*” sets forth the federal regulations for licensing, record keeping and reports, and storage of explosives. RPSC Blasters adhere to these regulations.

Title 49 of the Code of Federal Regulations of the Department of Transportation (various Parts) sets forth the federal regulations for

transportation of explosives. RPSC Blasters do not normally concern themselves with the broad explosives transportation issues to and around the Antarctic continent. Rather, such broad issues and compliance with regulations are the concern of Hazardous Cargo Specialists. Hazardous Cargo Specialists, furthermore, work within both civilian and military codes for explosives transportation. RPSC Blasters will assist Hazardous Cargo Specialists where appropriate, but normally the Blasters are concerned only with transporting explosives to and from magazines, blasting sites, and transportation delivery sites.

Mine Safety and Health Administration (MSHA) regulations under Title 30 CFR volume I, chapter 1 parts 56 through 58 may also apply.

State Licensing/ Permitting Requirements

RPSC Lead Blasters are required to be permitted or licensed explosives users. The permit to use explosives is generally issued on a State by State basis. Recently, RPSC Lead Blasters are permitted by the Colorado Department of Labor and Employment, Public Safety Section with a “Permit to Use Explosives”. Under the terms of that permit, the Blaster is required to abide by Explosives Regulations of the Colorado State Division of Labor.

Colorado also requires permits to “purchase” explosives. The Lead Blaster (FY 95-96) has confirmed with the Division of Labor that RPSC, headquartered in Colorado, is exempt from permitting requirements to “purchase” explosives.

Job Descriptions

Lead Blaster – License required

Blaster Assistant – License not required

Records

Record Identification, Format, & Owner	Active Location Storage, Protection, & Retrieval	Facility Storage, Protection & Retrieval	Retention Time	Ultimate Disposition
Annual Blasting Report, Electronic (MS Word), Lead Blaster	Lead Blaster's Office, Computer Password Protected, By request to Lead Blaster	N/A	5 years	Delete
Magazine Transaction Record, Hard Copy, Lead Blaster	Separate document stored in each explosives magazine, Secured Area, By request to Lead Blaster	N/A	5 Years from last entry	Recycle

Attachments, Appendices

Appendix 1: Fleet Operations Report for Blasting

