From:	Mark Valeriote
To:	"Greg Blaylock"; Rykaart, Maritz; Wade, Lowell
Cc:	Nick Stoneberger; Trevor Herd; mikepr@nunalogistics.com
Subject:	FW: Blasting Frozen Ground
Date:	Tuesday, February 01, 2011 10:22:18 AM
Attachments:	2333_001.tif 2332_001 (3).pdf

From: Jones, Kevin [mailto:KJones@eba.ca]
Sent: Tuesday, February 01, 2011 10:57 AM
To: Mark Valeriote
Subject: Blasting Frozen Ground

Mr. Valeriote

I dug out the Polar Gas ditching trials report and copied the relevant section (attached scan). I also copied a page a small reference from Branko's book.

KJ

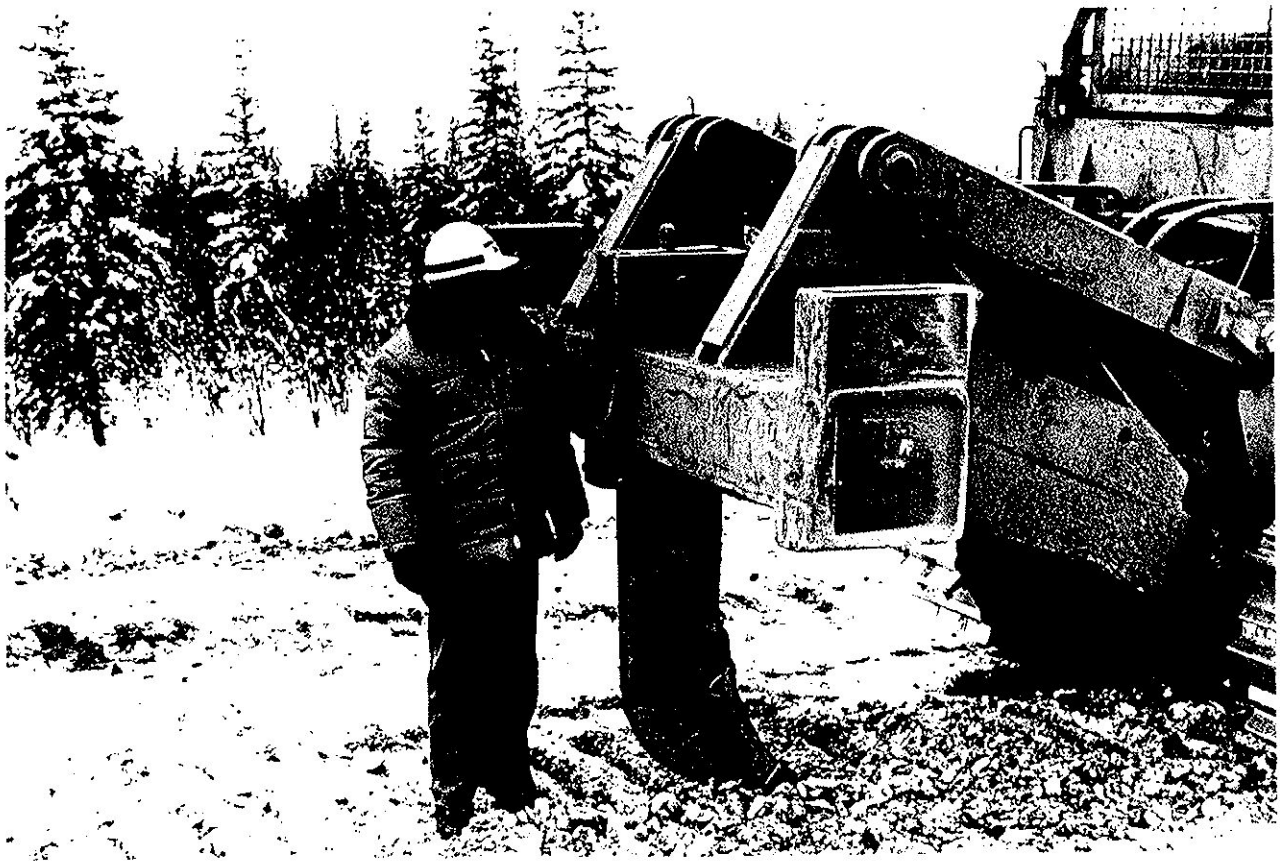

Figure 9-9. Single-tooth ripper unit attached to a D-9G Caterpillar tractor. (Courtesy of Francis H. Sayles, U.S. Army, CRREL.)

that extreme difficulty was experienced in ripping saturated gravels when the ambient air temperature was −40 to −46°C. At warmer temperatures (April and May) when ground temperatures were in the range −1 to −4°C, a single tractor could rip the same frozen gravels easily. Frozen soils with very low moisture contents (drained sands and gravels) can readily be loosened at any temperature and in some cases with about the same effort as that required in the unfrozen state.

Drilling and Blasting

Ice-saturated and frozen soil materials are very similar to rock formations. Excavation of these materials requires blasting in a manner similar to that used in quarries (Tart, 1983). Baker and Johnston (1981) stated that "drilling and blasting is the most economical method for dealing with the large quantities of frozen material involved in a mining operation."

The drilling operation and proper placement of explosive charges determines the effectiveness of the blasting method. Foster-Miller Associates (1973) and Mellor and Sellmann (1975) discussed how a reduction in hole depth and diameter, or plugging of the hole (melting and slump within the hole), may not permit placement of the explosive charge at the correct depth. A common problem in drilling is caused by meltwater freezing and forming an ice collar around the top of the hole. This ice collar and sloughing prevent proper stemming of the hole. Use of clean dry sand or fine rock chips to fill the hole helps achieve the required stemming. Particle size should not exceed 10% of the hole diameter. Swinzow (1963) achieved excellent results in permafrost using a mixture of silt and clay that was tamped in the hole and allowed to freeze. Mellor (1989) provided more information on stemming of shotholes.

Explosive consumption in frozen materials is high. Tart (1983) stated that "powder factors ranging from 1 to 2 lb/cu yd (0.6 to 1.2 kg/m^3) are typically used." A large proportion of the energy generated by the blast is absorbed by the ice for ice contents greater than 10% by dry mass. Since drilling and blasting is relatively expensive, most contractors prefer to keep their hole spacings as large as practical. Tart (1983) gave a typical spacing of 3 m between shot holes. This spacing, in overburden with high moisture contents, can give chunk sizes approaching 3 m unless the powder factor is appropriately increased or the hole spacing is reduced. The larger chunk size requires use of end-dump haulers. Livingston (1956) and Bauer et al. (1965) reported on