

Rose, this responds to the inquiries you sent to IME via email on August 17 and August 25. Your questions are addressed, in turn, below.

Question 1: Under what conditions (e.g., below the water table, competent bedrock) would perchlorate-containing blasting agents be used?

Response: As you probably are already aware, products classified as “blasting agents” and “explosives” are treated distinctly under most federal and state regulatory schemes. Nevertheless, in an effort to avoid any confusion that might arise regarding the use of these terms, I’ve included the following background and terminology discussion as a prelude to answering your principal question.

Background and Terminology

The term “blasting agent” is a term of art/regulation referring to the classification by the U.S. Department of Transportation (DOT) of a product as a Division 1.5 material. Division 1.5 “blasting agents” are extremely insensitive materials that can be safely transported without the precautions required for more sensitive “explosives” products. Sensitivity (the ease with which a product can be detonated), is determined using certain prescribed testing procedures.

ANFO (ammonium nitrate/fuel oil) is the most common type of Division 1.5 blasting agent. To the best of our knowledge, perchlorates are not used as an ingredient in ANFO. Because of its solubility, ANFO is impractical for use in wet conditions (in order to be used effectively in wet conditions, ANFO must be cartridgeed or placed in lined bore holes). This limitation on the effectiveness of ANFO spawned the development, during the 1960’s, of water resistant blasting agents and explosives – water gels, and emulsions.

A “water gel” is an explosive material containing substantial portions of water, oxidizers and fuel, plus a cross-linking agent. IME SLP 12 “*Glossary of Commercial Explosives Industry Terms*” (2002). An “emulsion” is an explosive material containing substantial amounts of oxidizer dissolved in water droplets, surrounded by an immiscible fuel, or droplets of an immiscible fuel surrounded by water containing substantial amounts of oxidizer. IME SLP 12 “*Glossary of Commercial Explosives Industry Terms*” (2002). Products such as butter, milk, latex paint, and shoe polish are also “emulsions.”

As an historical note, “emulsions” are referred to as the “next generation of explosives,” following the development of water gels. International Society of Explosives Engineers “*Blasters Handbook*” p. 26, 17th Ed.



(1998). Water gel products are still manufactured today but emulsion products represent the greater market share.

Most water gels and emulsions are manufactured as Division 1.5 extremely insensitive "blasting agents." If desired, the sensitivity of these products can be increased by adding a greater amount of a sensitizing agent. Depending upon the degree of increased sensitivity (determined by testing), the DOT classification of the material and associated regulatory requirements may change. E.g., a detonator-sensitive or "[blasting] cap-sensitive" product is not classified as a Division 1.5 "blasting agent." Rather, cap-sensitive products are classified by DOT as Division 1.1 "explosives."

Water gels may be sensitized using chemical sensitizers such as nitrate salts of organic amines, nitrate esters of alcohols, fine particle size aluminum, or other explosives. The products may also be sensitized using physical means such as entrapped air or "microballoons" (hollow bubbles of glass) either alone or in combination with chemical sensitizers. Chemical sensitizers are not typically used to affect the sensitivity of emulsion products, although some manufacturers do use chemical means to increase sensitivity as well as enhance other explosive properties. More often, however, increased sensitivity in emulsion products is achieved using a density-reducing agent such as microballoons, occluded air, perlite, or AN prills. See, ISEE "*Blasters Handbook*" pgs. 71, 82, 17th Ed. (1998).

Perchlorates may also be used to increase the sensitivity of water gels and emulsion products. For example, emulsion explosives may include sodium perchlorate to increase shock initiation sensitivity – the ease with which the product can be detonated by external shock (propagation and air gap sensitivity within a borehole as opposed to sympathetic detonation between boreholes). It is important to note, however, that the volume of products sensitized with perchlorates, when compared to the total volume of commercial explosives, is extremely small. Perchlorates are primarily used as the sensitizer of choice when a finished explosive product is designed for difficult blasting applications and/or those requiring high energy.

The development of perchlorates pre-dates the inception of the commercial explosives industry, but the availability and cost of the chemicals limited their use by early explosives manufacturers. With the onset of the U.S. space program, the availability of perchlorates improved. Perchlorates are both an effective and safe chemical sensitizer, and as such have become the sensitizer of choice when higher energies are required. The cost of perchlorates does, however, remain relatively high and this

impediment has limited perchlorate use to applications where the highest level of explosive performance is required.

Conditions For Use of Water Gel and Emulsion Blasting Agents

According to the ISEE Blaster's Handbook, emulsions have a "continuous, water-immiscible oil phase and are extremely water resistant." Further, "emulsions are a good choice when wet holes are encountered, because they will perform successfully after sleeping underwater for weeks or even months." ISEE "*Blasters Handbook*" p. 82, 17th Ed. (1998). Regarding water gels, ISEE states; "The water resistance of water gels is generally very good, but like dynamites it can be significantly decreased if the products are not used in the proper manner." ISEE "*Blasters Handbook*" p. 74, 17th Ed. (1998).

Given the physical properties of water gels and emulsions described above, it is not surprising that a blaster will often choose to use these water-resistant products when wet conditions are encountered. However, the particular sensitizing agent used in a water gel or emulsion is unrelated to the products' water resistance properties. Rather, the selection of an appropriate explosive (and sensitizing agent) is determined (in part) by the resilience that will be required to compensate for the dynamic and/or static pressures encountered in the blast area. Excessive dynamic and static pressures can be encountered in either wet or dry conditions.

Blasting agents or explosives sensitized with perchlorates can be used in high pressure, high energy applications where the explosive is subjected to relatively high static and/or dynamic pressures. When used in water gel and emulsion explosives, perchlorates can enhance the explosive performance of the product under these conditions.

For example, in certain instances, water-saturated ground can create an environment where the dynamic and static pressure waves created by column pressure and sequential (timed) blasting can damage and reduce the sensitivity of an explosive. The pressures encountered in this situation act to compress or destroy the gas or microballoons that are the standard sensitization mechanism for water gels and emulsions. In such applications, perchlorates have been found particularly effective in maintaining the sensitivity of the explosive, even if some of the primary sensitizing microballoons are destroyed.

Perchlorate-containing explosives typically have a high density (i.e., they sink in water) and also a high explosive energy (on volume basis) making them suitable for either wet/hard/dense rock blasting applications, or in general blasting applications to expand drilling patterns or to address

excessive rock burdens. Additional situations where high energy and high explosive distribution characteristics are appropriate may include, but are not limited to, tight underground cuts (e.g., tunnel construction), tight trenching applications (2/3 or 3/3 patterns), high pre-compression conditions, deep wet trenches, and deep wet boreholes.

It is interesting to note, however, that the very properties that make water gels and emulsions appropriate for wet conditions are those properties that limit the release of perchlorate (or any other chemicals) into groundwater. The binding of the perchlorate in the emulsion or the gel matrix provides an effective barrier to water. The rheology of emulsions or gels further contributes to the retention of perchlorate by maintaining its integrity in the borehole. Lastly, perchlorate-containing products are delivered as packaged products. The packaging material prevents diffusion and dissolution of the explosive.

Question 2: How common is the use of perchlorate-containing blasting agents?

Response: Unfortunately, we do not collect or maintain the type of data that would allow us to accurately estimate the quantity of perchlorate-based commercial blasting agents produced or used in the U.S.

We can tell you, however, that the use of perchlorate-containing blasting agents is very limited. As we noted above, perchlorate-containing commercial explosives and blasting agents are used in specialized high pressure, high energy applications. These products are manufactured and used specifically as an alternative to nitroglycerin (NG) based explosives products. Accordingly, given that NG-based explosives make up approximately 0.4% of the total commercial explosives market in the U.S., the perchlorate-based commercial explosives market can reasonably be projected to be even smaller.

In addition, the percentage of perchlorates as an ingredient in blasting agents is very low. For example, MSDSs for products manufactured by one of our member companies provide the following information: Bulk and Packaged Water Gel products - 0 to 4% Sodium Perchlorate; Packaged Continuous Water Gel Explosive - 0 to 7% Sodium Perchlorate.

Question 3: Can you provide information on specific agents and contacts for the manufacturers of these agents?

Response: We assume that you are requesting information regarding manufacturers of commercial explosives whose products may contain perchlorates (as opposed to information on perchlorate manufacturers).

The IME website at _____ includes links to our member companies' websites. Many of our members provide online access to MSDS information for all their company's products. The MSDSs will clearly indicate whether a particular product contains perchlorates, and in what percentages.

We also would like to provide you with some additional information regarding the effect of detonation on perchlorate-containing explosives and blasting agents.

The minimal quantity of perchlorates used in commercial explosives and blasting agents is unlikely to pose a significant threat to the environmental quality of the area in which such explosives are used. Explosives products that are properly detonated will result in a complete conversion of any perchlorates in the product. Specifically, the detonation reaction will result in the attachment of the chlorine molecule to either a sodium or potassium molecule to form the salts NaCl or KCl chloride. Even in a less than optimal detonation, only a negligible quantity of residual unconverted perchlorates will remain after the blast. Accordingly, any perchlorate contamination directly associated with blasting is more likely attributable to pre-blast loss of product such as improper spill cleanup, or misfires (misfires are a serious safety concern at a blast site and inordinate care is taken to avoid their occurrence. Consequently, misfires are relatively infrequent. When misfires do occur, the situation is immediately addressed by the blaster to eliminate any potential hazards, including environmental hazards, posed by the situation).

It also is important to recognize that the reaction chemistry involved in a detonation differs dramatically from the effects associated with the burning of perchlorates (e.g., in OB/OD units). While burning or deflagration activities may leave residual perchlorate, the detonation of perchlorate-containing materials does not.

A number of IME member companies are currently conducting controlled post-blast testing and analysis to definitively demonstrate that the detonation of perchlorate-containing explosives and blasting agents does not result in the release of residual perchlorates. This testing is in a preliminary stage at present.