Department of **Employment, Economic Development and Innovation**

Bulk Blasting Explosives

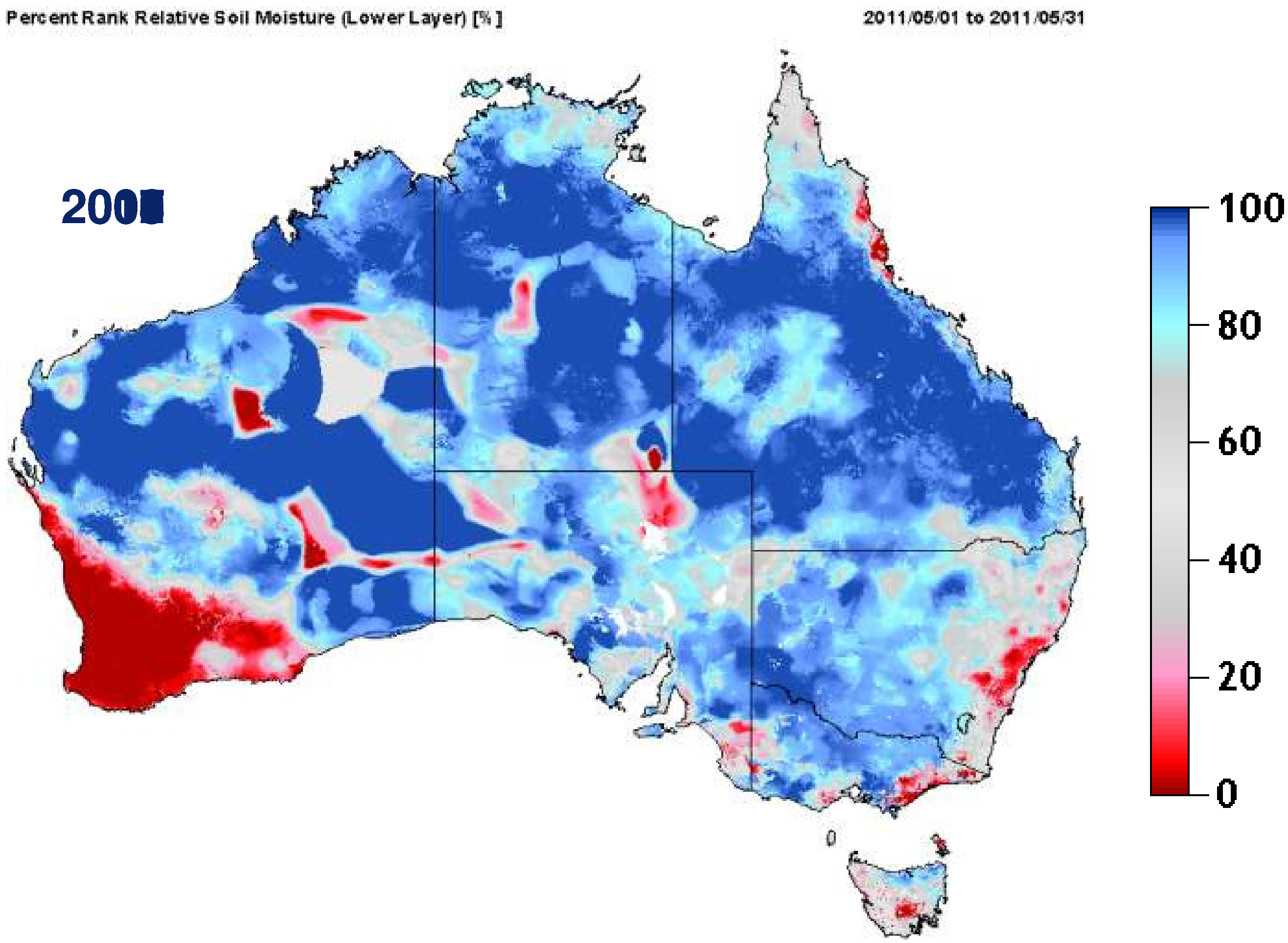
Post blast fume: Contributors and Prevention

Queensland Government

INTRODUCTION

- All nitrate based blasting explosives produce large volumes of gas in very short time frames
- Under ideal detonation conditions the gases produced are nitrogen, carbon dioxide and water (vapour) – all colourless gases
- Under non ideal detonation conditions undesirable gases are produced including oxides of nitrogen (NO, NO_2) and carbon monoxide
- NO_2 is a red coloured gas – it is the observation of this gas after a blast which is commonly described as “post blast fume”
- Many causes can contribute to non ideal detonation of nitrate based blasting explosives as used in practical mining situations.
- Over the last two years there has been a significant increase in post blast fume events observed in Queensland – why ??

SOIL WATER CONTENT 2001 - 2010



Source: CSIRO – Water Availability Project http://www.eoc.csiro.au/awap/

CONTENTS

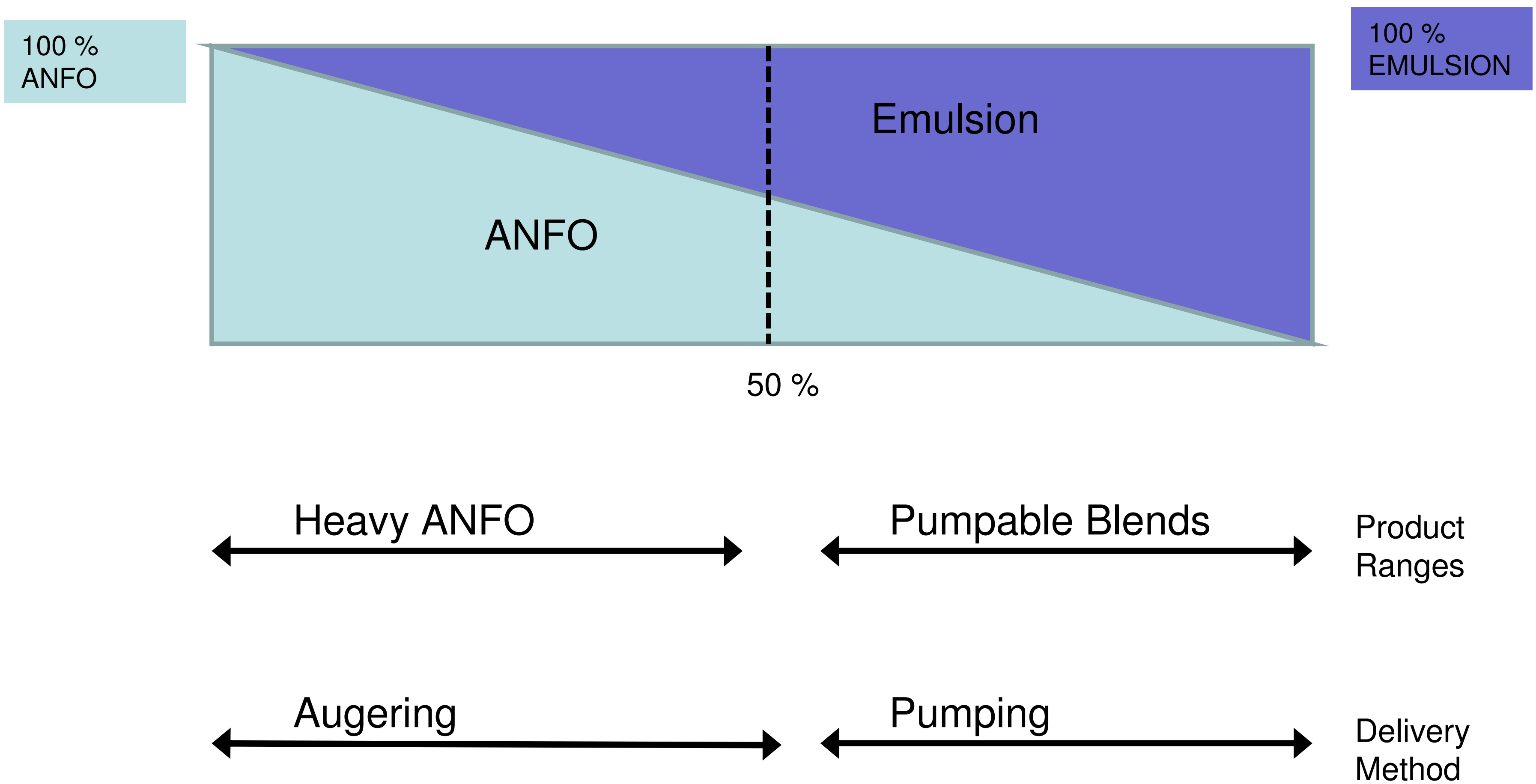
CONTEMPORARY BULK EXPLOSIVES

- An explosive is defined as:

"… mixture of materials which, when initiated, undergoes a rapid chemical change with the development of heat and high pressure to produce an aural, visual or practical effect…"

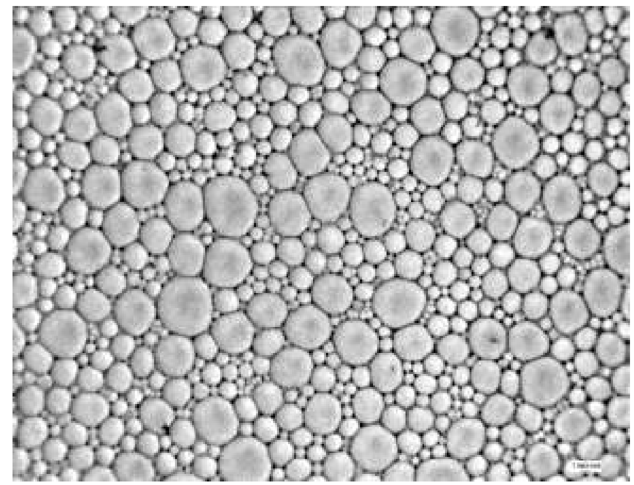
- Bulk explosives as used in mining applications typically comprise mixtures of the precursors:
  - Ammonium Nitrate
  - Fuel
  - Emulsion or watergel matrix (containing nitrate salts and fuels)
- These precursors are combined at defined ratios to produce explosive products of varying properties and attributes

PRECURSOR COMBINATIONS



EMULSION PRECURSOR

- An emulsion is defined as a mixture of two immiscible liquids stabilised by the presence of emulsifiers



- Emulsions as precursors for explosives:
  - Mix concentrated solutions of nitrate salts with fuel blends containing oils and emulsifiers
  - Made using processes which create a dispersion of nitrate salt solution droplets in a continuous fuel blend phase
  - High level of water resistance due to the presence of the continuous outer fuel blend phase

PRODUCT DESIGN AND DEVELOPMENT

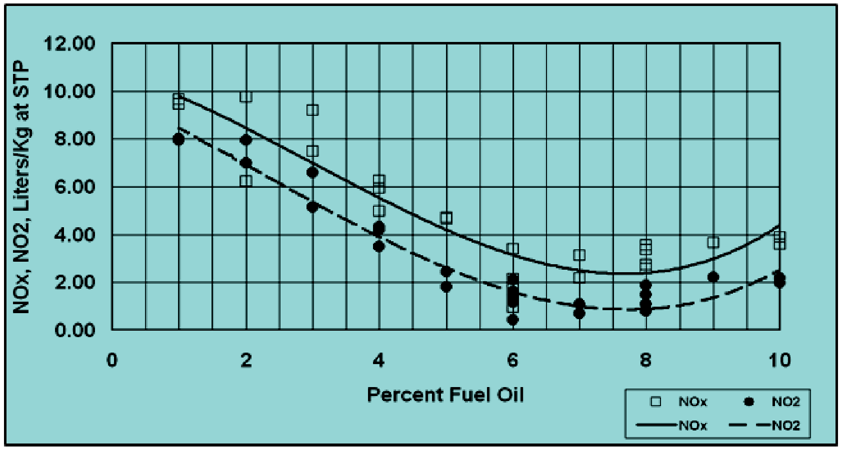
Numerous factors are considered in the design and development of a bulk explosive product. These include:

- Energy
- Oxygen Balance
- Sensitivity
- Water Resistance
- Stability
- Ease of manufacture and delivery

The following sections discuss those aspects of product design that can impact detonation, and hence the generation of post blast fume

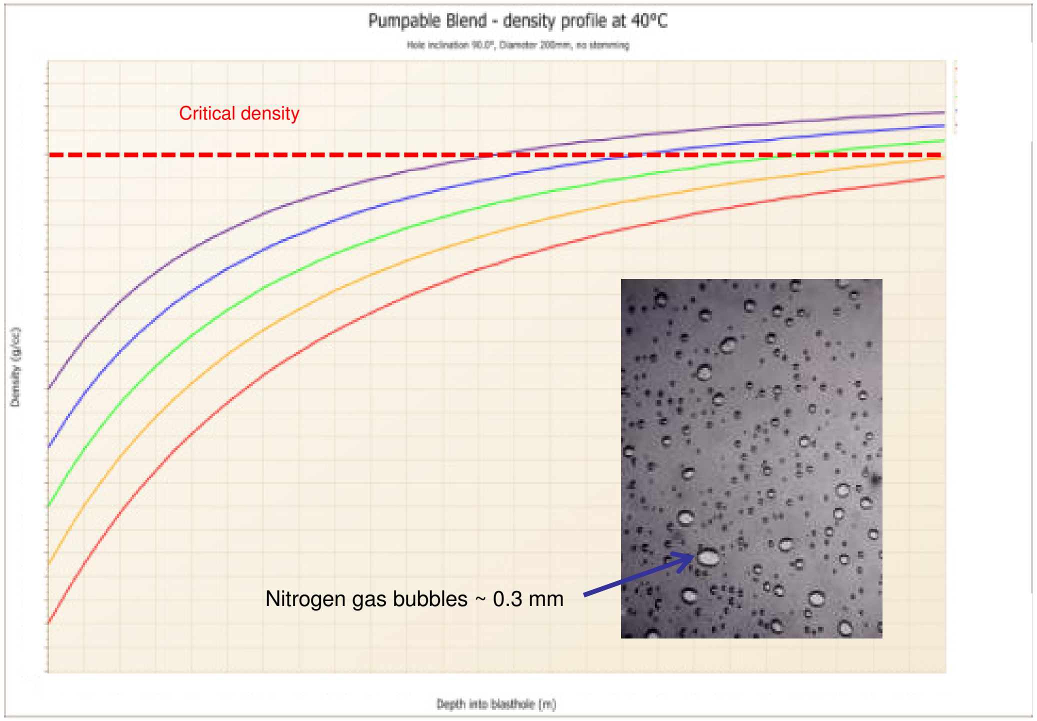
OXYGEN BALANCE

- Oxygen balance is a term used to define the ratio of oxygen to fuel in an explosive product.
- It is vital to ensure the correct amount of oxygen is available in the formulation for the available fuel.
- Deviation from ideal oxygen balance in an explosive formulation result in non ideal detonation and generation of non desirable gases:
  - Not enough oxygen – CO
  - Too much oxygen – NO/NO_2 (fume !)
- Explosive manufacturers formulate their products through the design stage to ensure that oxygen balance is fundamentally balanced.



SENSITIVITY

- If an explosive lacks inherent sensitivity for its intended applications, sub optimal detonation, post blast fume and even failure can occur.
- The sensitivity of contemporary bulk explosives relies on the presence of voidage.
- Voidage provides local "hot spots" within the explosive matrix that concentrate heat and act as localised points of initiation in the charge column.
- Where gassing is used, for sensitisation of pumpable blends, hydrostatic head effects must be taken into consideration to characterise density behaviour and depth constraints.



SENSITIVITY …

- Design and development of new explosive products include density and sensitivity characterisation to allow determination of in hole application boundaries. These include:
  - Minimum primer
  - Minimum diameter
  - Maximum depth

- Once established, these represent the recommended application boundaries of an explosive product as defined in explosive suppliers Technical Data Sheets

- Where explosive products are applied outside these recommended boundaries, non ideal detonation may occur resulting in sub optimal performance and post blast fume.

- Worth noting: In some application conditions and designs, dynamic effects during blasting can result in dynamic desensitisation of explosive products. Avoidance may require changes to design, product selection and blast timing.

WATER RESISTANCE

- Well known that ANFO rapidly dissolves in water.
- Emulsion (and watergel) explosives were originally developed to provide options for charging wet blastholes.
- Emulsions are inherently water resistant because the oils and emulsifiers in the continuous phase act as a barrier against rapid water penetration.
- When mixed with ANFO to produce final explosive products, emulsions and watergels, help protect against water damage.
- In general for bulk explosive products it can be said that:
  - Water resistance increases as emulsion level increases
  - Products with < 50 % emulsion are more readily damaged by water due to an increases surface area of exposure (gaps allow penetration)

WATER RESISTANCE …

Emulsion : ANFO blends showing impact on VOD when loading into various water levels in 150 mm diameter tube x 1.8 m long

Product **Emulsion : ANFO ratio**	**VOD (m/sec)**		
	Dry	75mm water	150mm water
ANFO	3,600	Failed	Failed
20/80 Blend	3,790	Failed	Failed
30/70 Blend	4,230	1,320	Failed
40/60 Blend	4,540	3,590	Failed
50/50 Blend	4,380	4,100	3,940

WATER RESISTANCE…

HANFO with 40 % Emulsion showing level of water penetration after 1 hour

WATER RESISTANCE …

- These factors are taken into consideration in the design of bulk explosive product ranges.
- Recommendations for product application based on blasthole water condition are provided in explosive supplier’s Technical Data Sheets.
- It is worth highlighting:
  - Emulsion and watergel explosives can be effected by water; they are water resistant but NOT waterproof
  - The extent of this effect is dependent on:
    - Sleep time.
    - How dynamic the water is.

PRODUCT STABILITY

- Contemporary bulk explosives are stable for a finite time ("shelf life").
- A product which is no longer stable will tend to suffer reduced water resistance and sensitivity.
- Stability is influenced by many factors including raw material selection/control, formulation, manufacturing and handling conditions, etc.
- Stability characteristics are determined during development and used to define appropriate sleep times as nominated in explosive suppliers Technical Data Sheets.
- During production, raw material inputs and process conditions for explosive manufacture/delivery are controlled to ensure product stability is not prematurely compromised.
- Detonation of explosives at sleep times beyond recommended limits may contribute to elevated levels of post blast fume.

DYNAMIC EFFECTS

- It is clear that poorly designed explosive products have the potential to contribute to elevated post blast fume.
- Product design requirements are understood and controlled by suppliers in order to “fundamentally” avoid post blast fume.

However !

- There are certain geological, confinement and blast design conditions in which high levels of post blast fume are consistently observed.
- Dynamic effects when blasting in such conditions are believed to influence some of the fundamental explosive design properties discussed above.
- These impacts are not well understood.

MANUFACTURE – QUALITY CONTROLS

PRECURSORS FOR MANUFACTURING EXPLOSIVES

- Usually manufactured at centralised facilities and delivered to regional or site locations prior to use
- Properties are critical to ensure:
  - Ease of handling in the supply chain and by mobile processing equipment
  - Optimal bulk explosives performance at end use
- Manufacturers have in place processes to monitor properties and ensure compliance with nominated specifications. Some are discussed here:

Porous Ammonium Nitrate Prill

Monitored for compliance to specifications:

- Bulk Density (porosity, sensitivity and metering)
- Fuel oil absorption (porosity and sensitivity)
- Friability (handling and metering)
- Size distribution (handling and metering)
- Water content (sensitivity and handling)

PRECURSORS …

Emulsion

- Emulsions are made up of a dispersion of nitrate salt (oxidiser) solution in a fuel/emulsifier blend
- QA parameters and raw material inputs are controlled to ensure final explosive products meet requirements for oxygen balance, sensitivity, water resistance and stability.
- Controls in the manufacture process to ensure these requirements are met include:
  - The use of defined and approved raw material sources
  - Raw material batch traceability
  - Nitrate solution concentration, pH and temperature control
  - Fuel blend temperature control
  - Calibrated or measured inputs of raw material flow rates
  - Process parameter monitoring and control during emulsion manufacture
  - Emulsion viscosity and temperature control
  - Reconciliation check of raw material inputs
  - Sample retention

FINAL PRODUCT MANUFACTURE

- Bulk explosives are generally manufactured and delivered into blast holes utilising mobile processing units (MPUs)
- These units carry precursors to the desired charging location and manufacture products directly into blastholes.
- The desired explosive products are made by combining precursors at predefined ratios.
- In order to ensure accurate metering of the various precursors, each MPU and each flow system on the MPU must be periodically calibrated.
- MPU calibration is critical to ensure explosive products conform to designed energy, oxygen balance, sensitivity, water resistance and stability requirements as defined in Technical Data sheets.
- When pumpable blends (or watergels) are delivered, samples are periodically taken during manufacture to allow monitoring and adjustment of product density.

STORAGE AND TRANSPORT

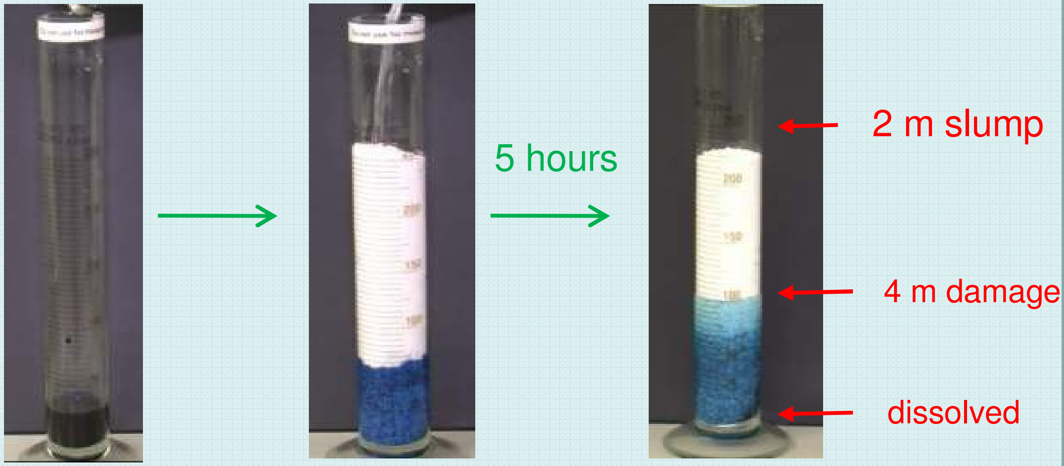
- Precursors for manufacture of explosives are made to defined specifications at centralised facilities and delivered to regional or site locations prior to use.
- Non ideal transport, storage and handling of precursors can cause degradation, which may compromise handling consistency and explosive product performance.
- The extent of degradation is influenced by numerous factors including, climate, transfer equipment/processes and time.
- It is possible to limit the rate and extent of precursor degradation by minimising:
  - Storage time
  - Exposure to climatic conditions
  - Rehandling
  - Temperature cycling
- Where precursor degradation has been identified, it may be necessary to manage its use in an alternative manner in order to minimise potential impacts on explosive performance.

BULK PRODUCT TYPES AND ATTRIBUTES

ANFO

- ANFO is made up of porous ammonium nitrate and fuel oil
- Augered or blow loaded into blastholes
- Most common blasting agent for dry hole conditions
- ANFO has <u>NO</u> water resistance

1 m water in 10m hole simulation



HEAVY ANFO

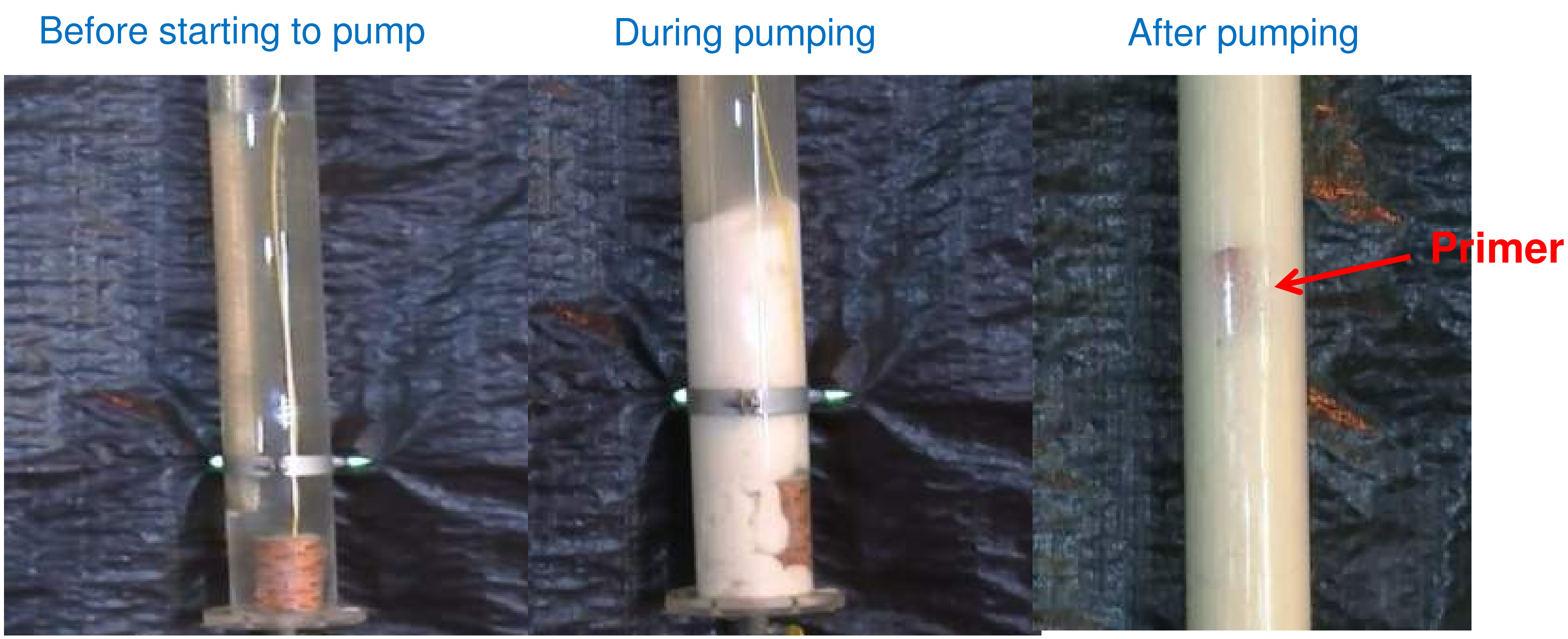
- HANFO products are made up of porous ammonium nitrate, fuel oil and emulsion in varying quantities.
- Manufactured at a range of densities
- Augered into blastholes
- Water resistance varies from poor to good with increasing emulsion content.
- High emulsion content HANFO products may be suitable for use in dewatered hole applications.

PUMPABLE BLENDS

- Pumpable blends are made up of porous ammonium nitrate, fuel oil, emulsion (or watergel) and sensitising agents.
- Generally available at a range of densities
- Pumped using a hose to the toe of blastholes to display water and minimise contamination
- Water resistance is excellent.

PUMPABLE BLENDS …

- Application of appropriate loading technique critical for performance and post blast fume:
  - Minimise water/mud contamination
  - Correct primer handling and placement



PRODUCT DELIVERY – DOWN THE BLASTHOLE

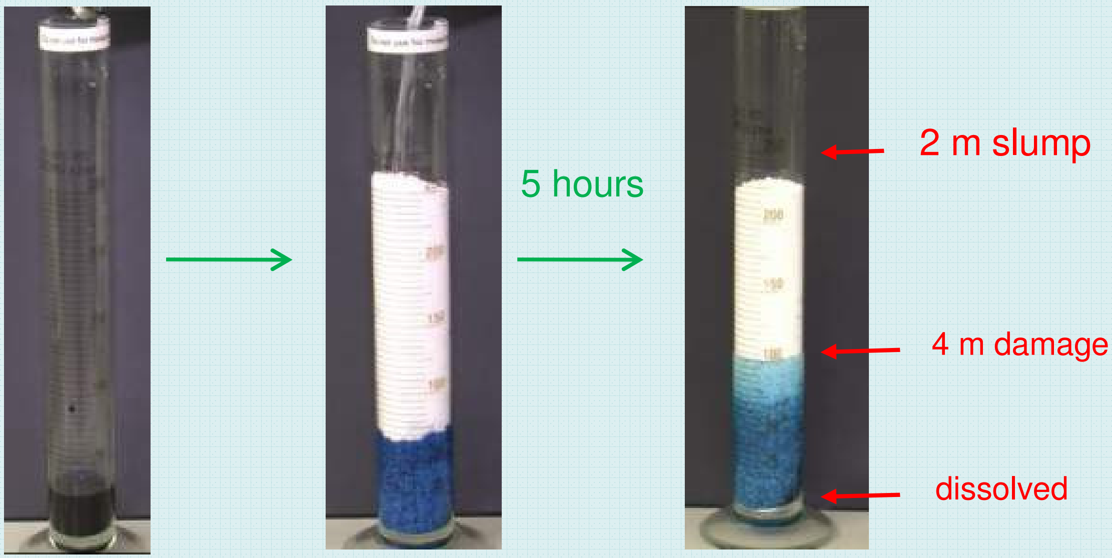
- The point at which bulk explosives are charged into a blasthole represents a crucial stage in the potential for post blast fume
- The following factors need to be considered and managed on bench before, during and after the blasthole charging process in order to minimise the potential for post blast fume generation:
  - Knowledge and application of products as per Technical Data Sheet recommendations
  - Understanding of the conditions in each blasthole (i.e. wet, dry, dewatered, cavities, etc)
  - Ensuring dewatering effectiveness and measuring recharge rates.
  - Avoiding water contamination of blastholes from surface water (rain, dewatering run off, washing out overload holes, etc)

PRODUCT DELIVERY – DOWN THE BLASTHOLE …

- Selection of the appropriate explosive products based on:
  - Specific individual blasthole condition (i.e. wet, dry, etc)
  - Having an understanding of ground type and hydrology
  - Anticipated sleep time and weather conditions
- Knowledge and application of correct charging techniques to ensure:
  - Minimal water occlusion and contamination
  - Minimal mud and drill cuttings contamination
  - Primers are in optimal contact with bulk explosive
- Failure to apply "good practice" in managing the above factors during the charging process will result in the generation of post blast fume.
- Some examples of poor charging practice and the impacts can be seen in the following slides.

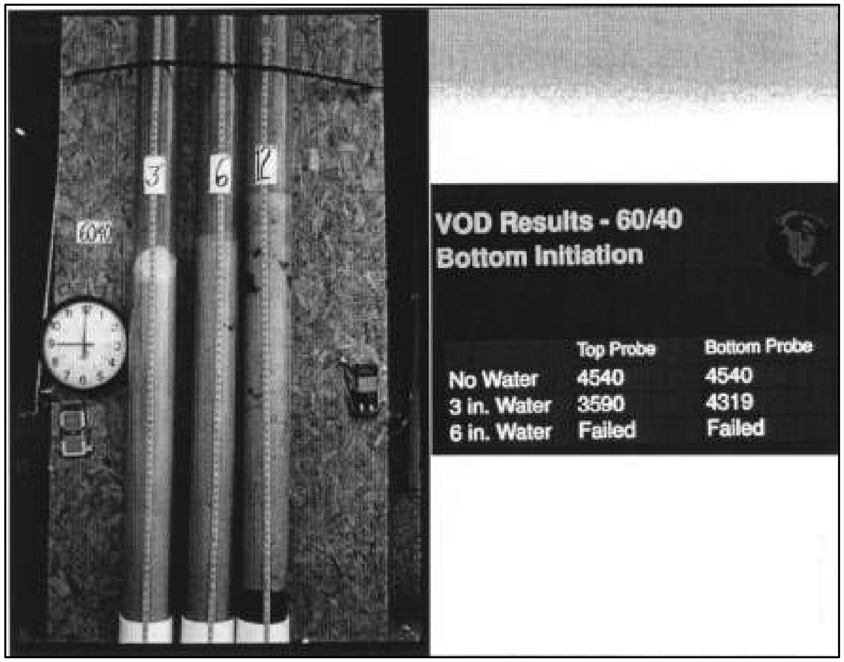
Loading ANFO into wet blast holes

1 m water in 10m hole simulation

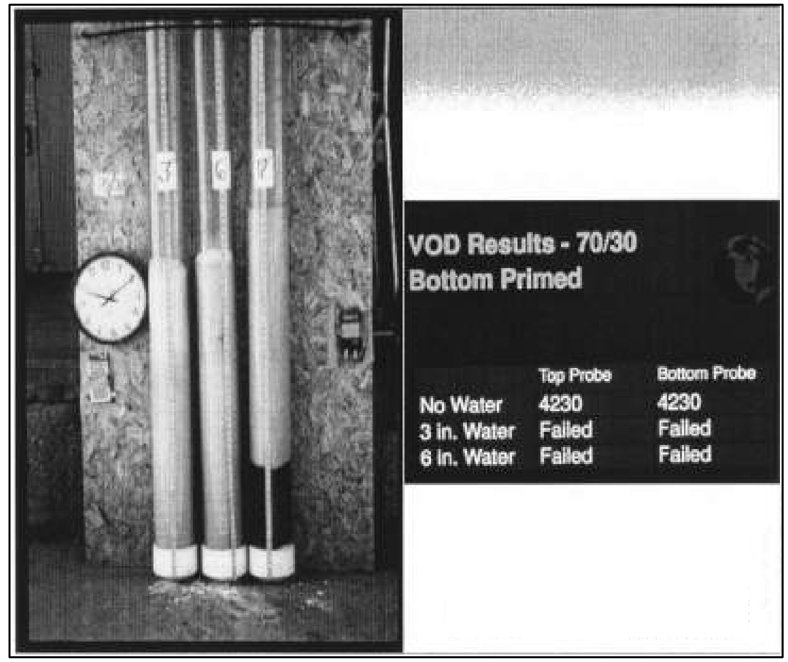


Impact of top loading HANFO into water

60 % ANFO : 40 % Emulsion



70 % ANFO : 30 % Emulsion



Augering HANFO product into wet blastholes - bridging

Poor hose handling during charging of wet holes with pumpable blends or watergels

Hose withdrawn too fast – excessive water contamination

Hose below primer during pumping - floating primer causing poor priming of bulk charge

Toploading of wet blastholes with pumpable blends and watergels

Before charging
Note: water dyed blue

After charging
10 cm water

After charging
50 cm water

OTHER FACTORS

- There are factors other than bulk explosive manufacture and delivery processes that have an impact on the generation of post blast fume including:
  - Blast design
  - Blast confinement
  - Blast dynamics
- The mechanisms involved are not yet fully understood.
- It is known that combinations of the following represent high risk fume applications:
  - Box cut and highly confined blasts
  - Soft and weathered ground types
  - Water saturated ground types
  - Highly fractured ground types
  - Blasts with high powder factors

CONCLUSIONS

- Bulk explosives are designed and manufactured to minimise post blast fume when used in accordance with Technical Data Sheet recommendations
- Dynamic effects when blasting under certain conditions are believed to influence some of the fundamental explosive design properties.
- Controls, decisions and practices applied at the time of blast hole charging can have a significant impact on the potential for post blast fume.
- There are many factors other than bulk explosive design, manufacture and delivery that contribute to the generation of post blast fume
- All mechanisms which can contribute to post blast fume in the practical mining environment are not yet fully characterised or understood.

QUESTIONS ?