Heavy ANFO Explosives (HANFO or Emulsion Blends)

It has been mentioned that dry ANFO products suffer from poor water resistance and low bulk strengths. One way to increase the bulk strength of the product is by mixing it with various amounts of emulsion. If larger amounts of emulsion are used the product can become water resistant. The resulting mix of ANFO prills with emulsion is ‘Heavy ANFO or HANFO’.

HANFO Composition

HAN/FO products consisting of a mix of an emulsion blasting agent with prills of ANFO or ammonium nitrate, where the percentage of each ingredient varies according to the desirable result. For wet conditions, a minimum of 50% emulsion is recommended.
For dry applications the percentage of emulsion depends on the bulk strength requirements and on the economics of the operation.
A variety of grades of ammonium nitrate prills can be used. The emulsion should have the consistency of a fluid so that it can be mixed with the ANFO prills easily. The main ingredients of the emulsion have already been discussed - ammonium nitrate, sodium nitrate, water, fuel oil and an emulsifier with calcium nitrate replacing part of the ammonium nitrate and/or sodium nitrate. Calcium nitrate requires a larger amount of fuel oil than ammonium nitrate for the oxygen balanced reaction. This reaction is;

$$3Ca(NO_3)_2 + 5CH_2 \quad 3CaCO_3 + 2CO_2 + 3N_2 + 5H_2O$$

To oxygen balance, 12.5 % by weight of fuel oil is required. Emulsions containing calcium nitrate are more water resistant, since they contain more fuel. Furthermore the product becomes more fluid which is desirable for mixing it with ANFO.
The table below shows the chemical composition of a typical calcium nitrate emulsion and the compositions of various water resistant HANFO products. For HANFO compositions containing large quantities of emulsion, the emulsion must be sensitized by microballoons or air bubbles.

TYPICAL COMPOSTIONS OF HANFO PRODUCTS

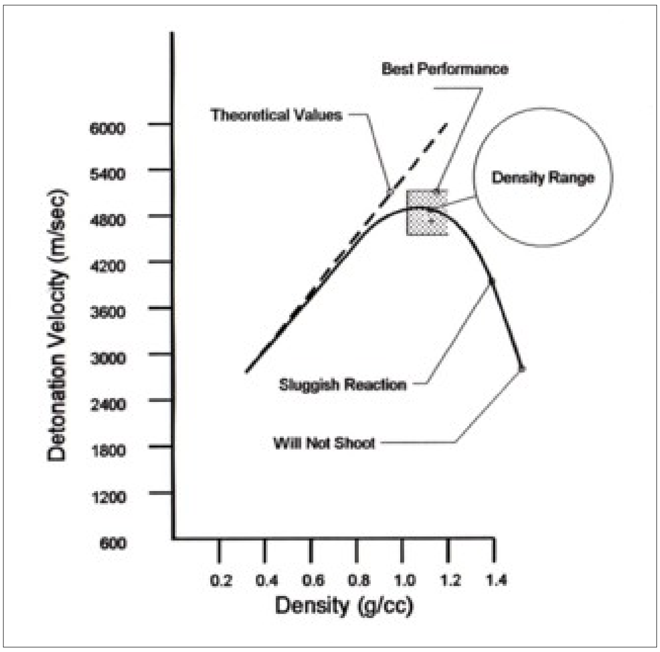
TYPICAL EMULSION COMPOSITION				
INGREDIENT	WEIGHT (%)			
AMMONIUM NITRATE	38.4			
CALCIUM NITRATE	35.8			
WATER	13.0			
FUEL OIL	10.8			
EMULSIFIER	2.0			
TYPICAL WATER RESISTANT HANFO COMPOSITIONS				
INGREDIENT	WEIGHT (%)			
AMMONIUM NITRATE	59.1	61.1	64.1	66.1
CALCIUM NITRATE	19.7	19.7	19.7	19.7
WATER	7.2	7.2	7.2	7.2
FUEL OIL	5.9	5.9	5.9	5.9
EMULSIFIER	1.1	1.1	1.1	1.1

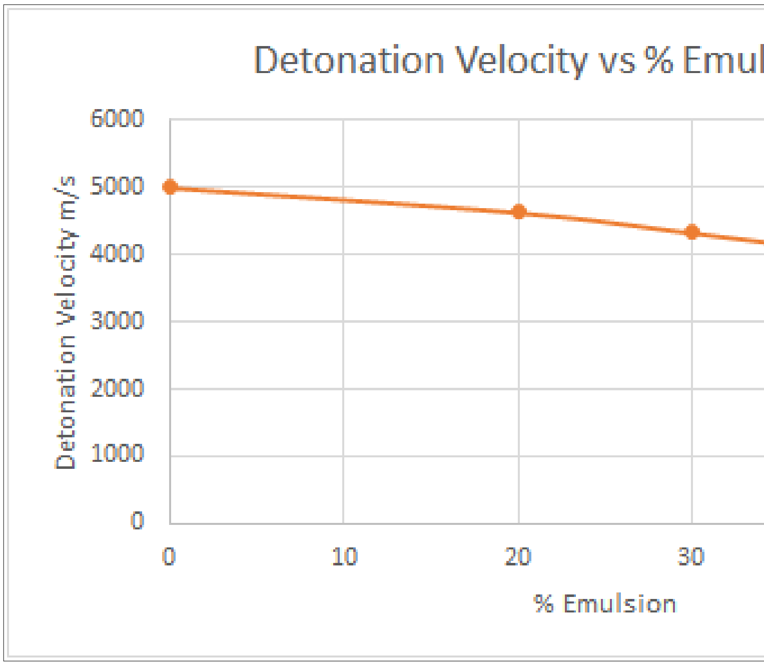
ALUMINUM	7.0	5.0	2.0	0.0

The next table below, shows some test results for different emulsion/ANFO blends. The first part of the table is for unsensitized emulsion added to ANFO and the second part shows the effect of the addition of microballoons to the emulsion. In the case of unsensitized emulsions the detonation velocities were found to be much lower than the theoretical ones. However the situation was greatly improved when sensitized emulsion was used. The results clearly demonstrate that sensitization of the emulsion is essential if the resulting product is to perform consistently well at emulsion concentrations higher than 25%.

WEIGHT (%) ANFO EMULSION	DENSITY (g/cc)	VELOCITY (m/sec)	THEORETICAL (m/sec)
100 0	0.83	5000	5100
80 20	1.01	4630	5470
70 30	1.10	4330	5700
60 40	1.23	4000	6300
50 50	1.30	3800	6460
WITH 1.6 % MICROBALLOONS			
80 20	1.0	5730	5370
70 30	1.1	5640	5700
60 40	1.2	6340	6220
55 45	1.2	5700	6280
50 50	1.25	5670	6340

The graph below shows the maximum velocity of detonation versus density of ANFO to which various percentages of unsensitized emulsion have been added.





Velocity as a Function of Density for ANFO and ANFO with Unsensitized Emulsion. Any dead-packe the method of packing/loading for an explosive product.

Performance of HANFO

HANFO compositions have large bulk strengths due to their density. If superior performance is required, aluminum can be added to the product. It is worth mentioning that the usual way of increasing the bulk strength of ANFO is by using aluminum. The table below shows the effect of the aluminum content to the energy output of the composition (reported as bulk strength). It is obvious from the table that the use of emulsion or aluminum in ANFO results in an increase of the bulk strength. The economics of the operation would decide which method is preferable.

STRENGTHS OF AL/ANFO AND HANFO PRODUCTS

EXPLOSIVE	DENSITY (g/cc)	RELATIVE WEIGHT STRENGTH	RELATIVE BULK STRENGTH
ANFO	0.83	100	100
5% AL/ANFO	0.87	113	118
7% AL/ANFO	0.88	118	126
10% AL/ANFO	0.91	124	136
ANFO + 20% EMULSION	0.98	96	113
ANFO + 30% EMULSION	1.10	92	122
ANFO + 40% EMULSION	1.20	91	132

Loading

Loading of the product in dry holes can be achieved by using an auger delivery system which drops the product inside the borehole. In wet holes this is not recommended. Tests have indicated that the product breaks apart on impact with the water and also it entraps water in the composition. It is recommended that if this method is used the product should be passed through a dry - liner which reaches the bottom of the hole where it is open ended. This way the product is loaded from the bottom up and water inclusions are avoided. Holes should be pumped dry first.

Another way of loading wet boreholes is by pumping the product. However in order to do this, the amount of solids has to be reduced to approximately 30% in the system. This means that the emulsion will have to be sensitized by voids in order to obtain consistent performance.

Priming Methods and Applications

To initiate commercial explosives effectively, explosives with high detonation pressures are used. These explosives, commonly called primers or boosters, are cap sensitive and they provide extremely high detonation pressures and temperatures main explosive columnar charge.

Properties of Primers

An explosive to be used as a primer must have a high detonation pressure and it must be cap sensitive. It is obvious that small weights of explosives having a large detonation pressure can initiate commercial products reliably. For this reason the most common primer today is the cast pentolite primer. Cast pentolite consists of 50% TNT and 50% PETN; it is cap sensitive and it has a detonation pressure of about 250 kBar. Normally priming weights used are from 4 to 6 times the minimum primer weight, determined at an unconfined charge diameter of somewhat greater size than the critical diameter of the explosive. Marginal priming, although not an acceptable practice is used when economics is really tight, since high quality cast pentolite primers are expensive. Usually a diameter 25 mm above the critical diameter is used. Trying to skimp and save at the priming end of the economics scale can sometimes be very costly. It has always been considered cheap insurance to over-prime rather than under-prime.

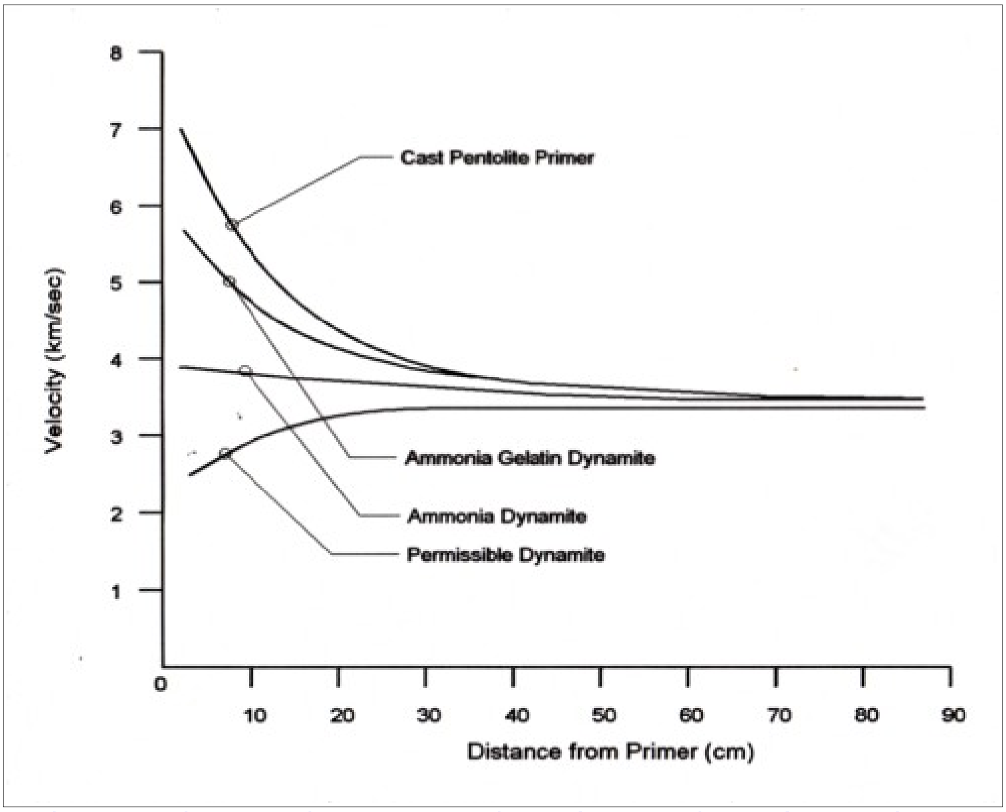
A variety of primers exist. As mentioned before, cast pentolite is the most common primer. Since PETN is expensive, another type of cast primer has been developed. These consist of a pentolite core which is covered by cast TNT. The pentolite core is sensitive to primacord and detonators, whereas the cast TNT is not.

During initiation the pentolite core is initiated and the resulting detonation this core initiates the TNT shell.

Emulsion and dynamite have been advertised as primers and have been marketed in the past few years. They are situated as an attractive alternative to higher priced pentolite primers - especially in the construction industry. These primers have good water resistance and good performance under hydrostatic pressures and low environmental temperatures.

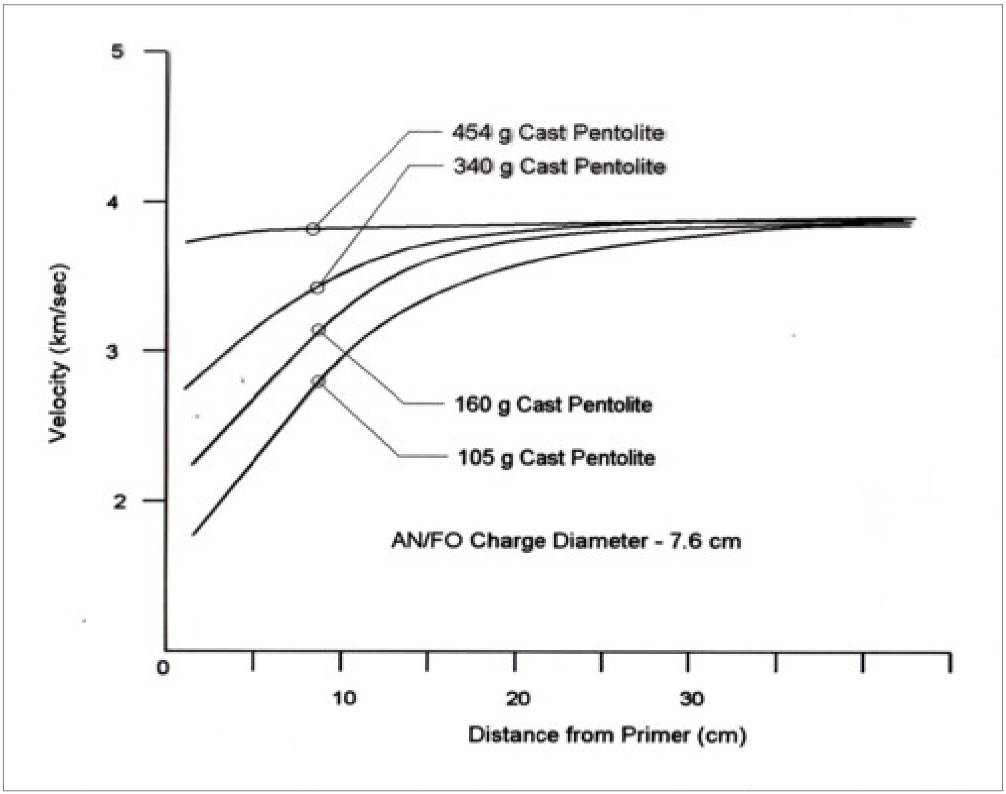
The pressures obtained by these products are in the order of 120 kBar-140 kBar. It is worth noting that emulsions and dynamites should be used with caution since these products can still be affected by severe conditions (extremely low temperatures and very high hydrostatic pressures).

The figure below illustrates the effect that primer detonation pressure has on the initiation of ANFO from a series of tests. Different types of explosive primers were used in the tests but the weight of primer remained the same. The weight of the primer was kept the same. It is obvious that high detonation pressure primers resulted in smaller transient regions in the explosive column. The initial detonation velocities of ANFO increased as the detonation pressure of the primer increased. However the final detonation velocity was the same. This is expected once a minimum primer weight has been exceeded.



Detonation Velocity Transients Near Primer for a Variety of Explosive Products

Another graph below shows the effect of the pentolite primer weight on the detonation velocity of ANFO. It is obvious that the initial velocity is affected by the primer weight. However the final velocity is always the same. These velocity effects are called transients and are dependent on primer geometry and weight. It is obvious that the overall performance of the ANFO and consequently of the other commercial products is not affected by the primer weight provided that this exceeds the minimum. Only the initial velocity is affected.
The primer diameter is another important parameter. It has been found that the initial velocity in the explosive is dependent on the diameter of the primer. It has been suggested that the primer diameter should match that of the borehole.



Run-Up Distances as a Function of Primer Weight

However this is not practical in large boreholes and it might result in unnecessarily large primer weights. The primer length is important because the primer should reach its maximum detonation state parameters soon after initiation so that it shocks the explosive charge with its full strength.

Priming Techniques

The location of the primer usually depends on the sensitivity of the explosive being used. If the explosive is sensitive to the detonating cord, or if the detonating cord desensitizes that by pre-shocking, the preferred location is the top of the borehole. If, however, the explosive is not affected by the detonating cord or if a different mechanism of initiation is used, the preferred location is the point of most confinement. This is usually the bottom of the borehole. Furthermore in hot holes (high sulfide content oxidizing ores) the primers should be placed last in the explosive column (top priming). However this is a safety issue and perhaps head resistant explosives should be used in this application.
Normally a second primer is used in long explosive columns along with a detonator having a time delay one period later. This prevents misfires due to cutoffs from shifting rock or rock that is extremely fractured.

References

•From Dr. Alan Bauer course notes
•From Dr P. Katsabanis course notes
•From C. J Preston notes from Queen's University Test Site, Dupont field testing