

Comparison of Ammonium Nitrate Additives

Various substances have been used over the years as additives to ammonium nitrate in commercial blasting applications. Initially, because the detonation of raw ammonium nitrate creates an excess of oxygen, carbon-rich substances were added to reduce the generation of nitrous oxide gasses and increase the available energy. Materials such as coal dust, sawdust and petroleum products were tested. Today, virtually all users of ammonium nitrate as a blasting agent use a blend of 94% ammonium nitrate and 6% diesel or fuel oil by weight ("ANFO"). This blend has a chemical energy of ~880 calories/gram.

Ammonium nitrate is relatively expensive (~\$400-\$500 per ton) and there have been various attempts to blend it with less expensive energetic materials to lower the overall cost of blasting. Most of these attempts have failed because they either negatively impacted the performance of the explosive or had adverse handling characteristics. The development of OS5, an oil shale additive, has overcome these limitations. The most often tried additive is coal. Another option proposed is rock asphalt, a naturally occurring limestone impregnated with bitumen. This paper compares these three options, looking at various pertinent characteristics:

- **Specific Gravity** – OS5 has a density of 1.05 grams per cubic centimeter, rock asphalt ~2.0 g/cc and bituminous coal 1.1 to 1.4 g/cc.
- **Porosity** – This property is important since oil is added to the ammonium nitrate in controlled ratios. An additive with a high porosity will affect the coating of each AN prill, affecting the performance. OS5 has a very low porosity of 0.4%. Coal has a porosity of ~27%. The porosity of rock asphalt is unknown but could be established by lab testing.
- **Moisture Content** – OS5 has a moisture content of 2% versus coal at 12%. Because of its higher porosity, changing atmospheric and storage conditions make the moisture in coal vary significantly, affecting detonation characteristics and often resulting in spontaneous combustion of the raw coal in storage. It is unknown how this parameter varies in rock asphalt.
- **Energy Content** – OS5 has 2190 calories per gram versus 880 calories per gram for ANFO. Both rock asphalt and coal have higher energies, but the values vary significantly. Rock asphalt has 2%-20% bitumen, with an average around 10%. This equates to an energy of ~3500 calories per gram. Coal varies as well, with an average around 8600 calories per gram. The variability in available energy in both rock asphalt and coal could produce variability in the results from a blast.
- **Hardness** – OS5 has a hardness of 60 grind versus coal at 35-40 grind. Hardness is a measure of the tendency of a material to break down and produce fines as it is handled. The lower the number, the more likely it is to create fines with repeated handling. The hardness of rock asphalt is unknown.
- **Environmental/Storage Considerations** – OS5 and rock asphalt are classified as ordinary rock and emit no hazardous fumes or other pollutants. They can be stored both indoors and outdoors with no special precautions. OS5 has been approved by MSHA for storage on mine sites. In areas of high temperature, OS5 remains stable but the free-flowing characteristics of rock asphalt can be affected. Coal can emit methane and its high porosity allows the moisture content to vary significantly. Spontaneous combustion of coal stockpiles is frequent and

rainwater runoff must be contained so local groundwater is not contaminated. Coal also tends to produce dust and fines.

In summary, OS5 is a desirable, tested additive that can reduce the cost of blasting while adding energy to the blast. It is stable and non-polluting and requires no special storage or handling. Coal is undesirable because of adverse storage and handling considerations and its tendency to spontaneous combustion. While rock asphalt may work in this application, extensive testing on its effect in the borehole and handling characteristics would need to be done before it could be recommended for use as an ammonium nitrate additive in blasting applications. Testing materials as additives for explosives can be costly and time consuming. OS5 has already been tested and approved.

Summary of Analysis

Property	OS5 Oil Shale		
Specific Gravity	1.05		
Porosity	0.4%		
Moisture Content	2.0%		
Energy Content	2190 cal/g		
Hardness (Fines Generation)	60		
Storage/Handling Issues	None		