17th International Mining Congress and Exhibition of Turkey- IMCET2001, ©2001, ISBN 975-395-417-4

Evaluation and Analysis of Blasting Procedures for Removing Hard Formations at the South Field Lignite Mine, Ptolemais, Greece

Z.Agioutantis
Department of Mineral Resources Engineering, Technical University of Crete, Hania, Greece

S.Bozinis
LCP-A, Public Power Corporation, Greece

G.Panagiotou
Department of Mining Engineering and Metallurgy, National Technical University of Athens. Greece

C.Kavouridis
Assistant General Director, Public Power Corporation, Greece

ABSTRACT: Drilling and blasting procedures are utilized for removing various types of hard overburden formations at the South Field Lignite Mine, at the Lignite Center of Ptolemais-Amydeon, operated by the Greek Public Power Corporation. This paper presents a statistical analysis of blasting performance parameters for a number of years as well as an evaluation of blasting results as recorded by mining personnel at the site. Appropriate blasting and overburden removal indices are also presented.

1 INTRODUCTION

Greece is the fifth largest producer of soft brown coal in the world and the second largest in the European Community, producing about 63Mt of lignite per annum. The Lignite Center of Ptolemais-Amydeon (LCP-A), operated by the Greek Public Power Corporation (PPC), is located in northern Greece, about 110km west of the city of Thessaloniki. The lignite deposits under exploitation cover an area of $120km^2$. This area includes approximately 4000Mt of proven geological reserves and about 2500Mt of exploitable lignite under current economic and technological criteria. Today (January 2001), the LCP-A operates four large lignite fields, which produce lignite used to cover 60% of power generation in Greece. At the present rate of extraction, 51Mt of lignite is produced annually (comprising over 80% of total lignite extraction in Greece), by moving a total volume of $250Mm^3$ (waste and lignite).

The South Field Mine (SFM) is the largest of the four operational surface mines at the Lignite Center of Ptolemais-Amydeon, covering an area of $24km^2$ (Figure 1). The original lignite deposit in the area was estimated at 1.2 billion tons of lignite. Mining operations commenced in August 1979 and the mine currently operates on ten benches, mainly using the continuous mining method, which employs bucket wheel excavators (BWEs), conveyors and stackers. For operational purposes, die field İs divided into 10 sectors (Galetakis & Agioutantis, 2000). Currently, sector #2 is being mined, while preparatory work is under way for sector #3. In addition to the continuous mining method, conventional mining equipment, including off-highway trucks, front-end loaders, electric rope and hydraulic shovels, dozers and mobile crushers, are utilized for mining the hard rock formations which are encountered in the overburden strata.

The South Field Mine can be considered unique regarding the mining conditions and the methods used to exploit the lignite deposit. More specifically, İn sector #2, benches la, lb, 2a, 2b and 3 are designed to excavate overburden, while benches 4, 5, 6a, 6b and 7 are set in the lignite seams. Sixty-five

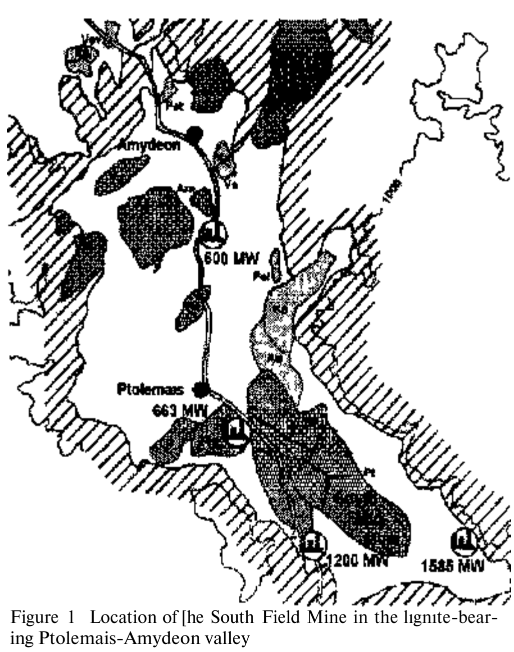


Figure 1 Location of[he South Field Mine in the lignite-bearing Ptolemais-Amydeon valley

conveyor belts with a total length in excess of 100km are installed in the SFM. The mining depth İs expected to reach 200m. The scheduled annual lignite production at the SFM ranges from I8-21Mt (covering about 33% of the total lignite production in Greece for the year 2000), while overburden removal operations produce 47-53Mm^3 of bank material annually. The volume of total annual excavations amounts to 90Mm^3 (Table 1). From the beginning of mining operations up to the end of 2000, 1005Mm^3 of total earth material was removed and 221Mt of lignite was produced with an average exploitation ratio of 3.75:1 (nvVt).

Table 1. Material handling at LCP-A.

Location	Lignite production (Mt/year)	Total excavations (MnvVyear)
South Field Mine	18-21	90
Other LCP-A Mines	30-32	160
Total LCP-A	51.5	250

2 OVERBURDEN REMOVAL OPERATIONS

Overburden strata in the SFM consist of fine and coarse clastic sediments such as clays, marls, gravel, conglomerates with embedded hard layers of sandstones, cemented conglomerates and mudstones. The average specific weight of the overburden is 19.62kN/m (2ton/m^3) and the average bulking factor ranges from 1.4 to 1.5. The average thickness of the overburden material is 90m. Table 2 summarizes the range of the mechanical and physical properties of the hard rock formations, while Table 3 presents the approximate extent of each formation at the SFM.

Table *2.* Range of mechanical and physical properties of the hard rock fo nn a tions.

Parameter	Range
Uniaxial compressive strength (MPa)	15-143
Tensile strength (MPa)	2.4- 11.2
Density (kN/m^3)	23.5 - 26.5
Density (ton/m^3)	2.4 - 2.7
Bulking factor	1.4- 1.5

Approximately 25-30% of the overburden consists of hard and semi-hard formations, which are removed using conventional mining methods, while the remainder is excavated by BWEs. As early as 1981, there was a decision to apply large-scale drilling-and-blasting operations to loosen the hard rock formations and to use mobile load-haul equipment to move the blasted material. The semi-hard formations within the overburden strata that cannot be excavated by BWEs are loaded by shovels without any blasting. It should be noted that one of the unique features of the overburden removal operations is that drilling-and-blasting and shovel-truck operations are considered supporting mining operations that should accommodate the needs and priorities of the primary excavation operations, which are carried out by BWEs.

Currently, five blasthole rigs (Tamrock C50 K.3L) are deployed, drilling over 1000 m of blastholes per day at 7^7 and 9in diameter in 4x5m or 6x6m blasthole grids. In recent years, about 1250-1650 tons of explosives were consumed annually (Figure 2) by detonating about 700 shots. That corresponds to 2-3 blasts per day, with the explosives' load ranging from 1 to 8 tons per blast. The drillheads are air-cooled tricones (IADC 622) with embedded carbide bids.

Originally, blasting was accomplished by utilizing ANFO mixes with either ammonia dynamite (extra dynamite) products or gelatin dynamite (30% weight strength) for boosters. Wet holes were loaded with 30% weight strength gelatin dynamite (Agioutantis, et al., 2000).

For the first time, in 1995, SFM engineers used a special mixture of ANFO and an emulsion called Heavy ANFO (H-ANFO), which was prepared in situ by mixing the emulsion (nitrate salts dispersed as small droplets in a continuous oil base) and porous ammonium nitrate. Several mixing ratios were evaluated for application in the SFM before selecting the optimum one (Agioutantis & Kavouridis, 1998). This mixture has relatively high bulk strength, a higher critical diameter (over 150mm), but good blasting characteristics in wet blastholes. Hence, ANFO is currently used in dry holes and H-ANFO İs used in wet holes. Ammonia dynamite is used as a booster to ANFO and gelatin dynamite as a booster to H-ANFO- or ANFO-loaded blastholes. The use of water resistant explosives has increased in recent years (Figure 3).

Table 3. Estent and dimensions of each overburden formation group (Papageorgiou & Pakas, 1997).

Rock type	Rock description	Area (km')	Average thickness (m)	Volume (Mm^3)	Percent (%)
Hard material	conglomerates, sandstone	24	11	264	13
	conglomerates, breccia	10.5	10	105	5.2
Semi-hard material	clay, sandstone, gravel	10.5	10	105	5.2
Loose material	clay	24	61	1464	72.3
	sand, gravel	22	4	88	4.3
Total		24		2026	100

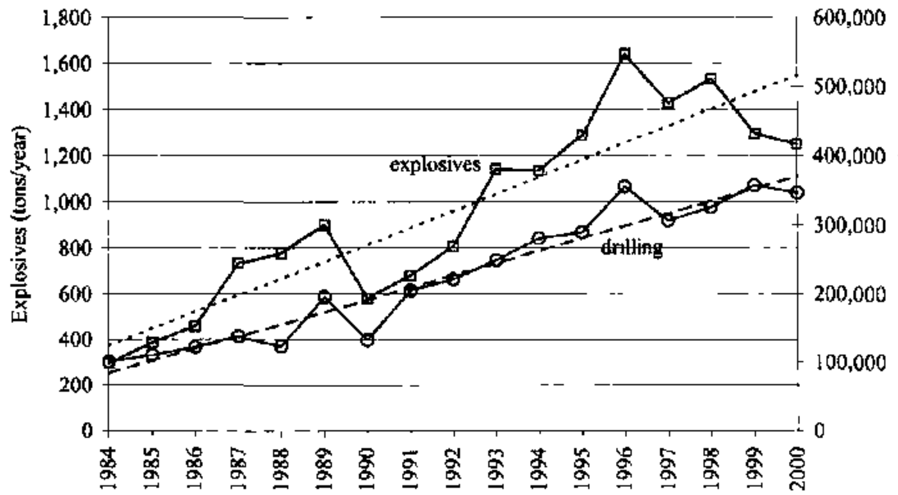


Figure 2 Total explosives consumption and total drilling at the South Field Mine.

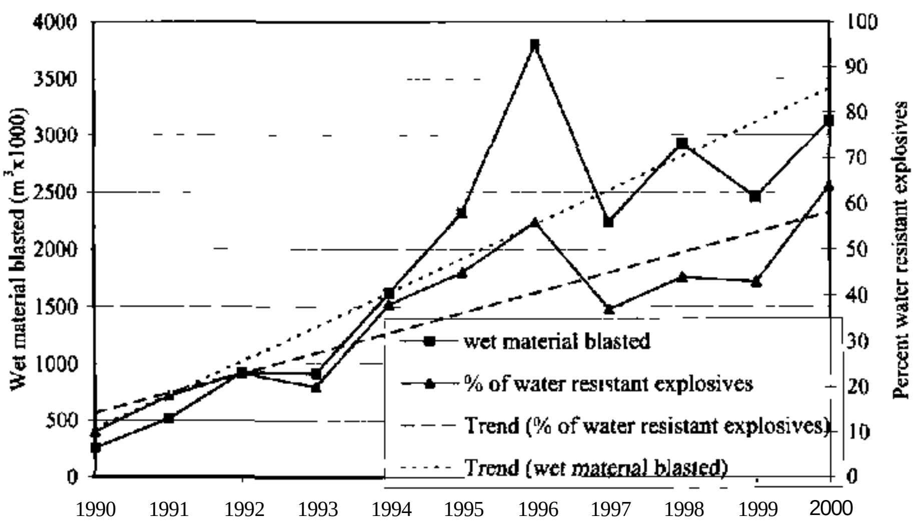


Figure 3. Wet blasted material and percent of water-resistant explosives used at the South Field Mine

The hard formation mining operations at the SFM employ about 240 people in 3 shifts moving approximately 13Mm of overburden material annually. However, in order to carry out mining plans for the preparation of sector #3, external contractors using conventional equipment excavate an additional $5Mm^3$ of overburden material. In summary, the PPC currently handles all of sector #2 mming (hard and soft rock formation removal) while contractors handle all of sector #3. In past years (1996, 1997), contractors were involved in sector #2 operations as well.

3 BLASTING PERFORMANCE STATISTICS

Figure 2 presents the total explosives consumption per annum and the corresponding total drilling effort in the SFM for the last 16 years. As is shown by the corresponding trend lines, both explosives consumption and drilling is steadily increasing. It should be noted that since the hard formation lenses are not uniformly distributed within the overburden, drilling and blasting statistics may experience fluctuations over a given time period.

Figure 3 presents the volume of the wet material mat was blasted and the corresponding percentage of water-resistant explosives used for these operations (e.g., H-ANFO) from the total amount of explosives used per annum for the last 10 years. Currently, the specific consumption is approximately 250g/m^3 of overburden.

Table 4 presents the distribution of me production of the hard and semi-hard overburden materials for benches lb, 2a and 2b (sector #2), The total production handled by conventional equipment ranged from 10 to 12Mm^3 per year for the period 1996-2000. BWEs removed volumes ranging from 10 to 15.6Mm^3/year, while contractors excavated smaller volumes (in 1996 and 1997 only). During the last five years, an average of 45% of the overburden volumes handled by the PPC were removed using drilling-and-blasting and shovel-truck operations.

Table 5 presents the total overburden excavations handled in the SFM, (using conventional equipment) between 1996-2000. This data includes excavations in sector #3 as well as in benches la and 3 (not included in Table 4), which account for only 10% of the total excavations. From the data presented in Table 5, the blasted/moved ratio of the hard and semi-hard waste material is calculated, showing that 44% of the excavated volume requires blasting. In practice, all hard rocks are blasted while semi-hard rocks are excavated directly. In this respect, drilling and blasting operations need to negotiate all aspects of hard formations, includmg thin hard lenses embedded in soft or semi-hard benches. In these cases, all soft and semi-hard material is directly removed, the hard lenses are blasted, and operations resume for the remainder of the bench. Therefore, it is not unusual to blast 2m thick ledges using 9in holes in 5x5 grids. Evaluation of the bench-specific data presented in Table 5 highlights the variability of the overburden material. For example, the need to blast overburden in bench lb decreased to 13%, compared to 96% in 1996, while the blasting requirement remained constant for bench 2a over the same time period.

Figure 4 shows the density distributions (histograms) of the drill hole depth using data collected during 1996 and 2000 (Bozinis, 2000). It should be noted that such data have been available through daily logs since operations started. It can be observed that the trend in 2000 is for shallower drill holes, which corresponds to thinner lenses. Figure 5 presents the corresponding cumulative distribution function for the same data.

Table 4. Distribution of production of hard and semi-hard overburden materials (m^3 x 1000) between BWEs and conventional excavation equipment (shovels) for benches 1 b-2a-2b (sector 2. oenod 1996-2000).

	1996				1997				1998			
	BWEs	Shovels*	Total	Ratio	BWEs	Shovels	Total	Ratio	BWEs	Shovels	Total	Ratio
	(1)	(2)	(3)	U>/(3)	(1)	(2)	(3)	(2)/(3)	(1)	(2)	(3)	(2)/(3)
bench-lb	3915	630'	4545	0.14	5058	2331"	7389	0.32	6642	916	7558	0 12
bench-2a	2894	4586*	7480	061	4186	4993*	9174	0 54	3737	5978	9715	0 62
bench-2 b	3649	5510'	9159	0 60	4381	5642*	10023	0 56	5358	4566	10124	0.45
Total	10458	10726*	21184	0.51	13625	12966'	26586	0 49	15737	11460	27397	0.42

	1999				2000				Totai \ 996-2000			
	BWEs	Shovels	Total	Ratio	BWEs	Shovels	Total	Ratio	BWEs	Shovels	Total	Ratio
	(1)	(2)	(3)	(2)/(3).	(1)	(2)	(3)	(2)/(3)	(1)	(2)	(3}	(2)/(3)
bench-lb	6908	1417	8325	017	4235	2415	6650	0 36	26758	7709	34467	0 22
bench-2a	2933	7294	10227	0.71	3972	7011	10983	0 64	17722	29862	47579	0 63
bench-2b	5799	2277	8076	0 28	5359	1197	6556	0 18	24546	19192	43938	044
Total	15640	10988	26628	041	13566	10623	24189	0.44	69026	56763	125984	0 45

partial contractor production is included

Table 5 Comparison of moved and blasted hard and semi-hard material (m^1 x 1000) al the South Field mine (period 1996-2000)

	1996			1997			1998		
	blasted(l)	moved (2)	ratio (1V(2)	blasted (1)	moved (2)	ratio (11/(2)	blasted (!)	moved(2)	ratio (l)/(2)
sector-3	301	330	0.91	546	677	081	1470	1550	0 95
bench-la*	15	20	0 75	0	1	0 00	52	60	0 87
bench-lb*	607	630	0.96	1595	2331	0.68	294	916	0 32
bench-2a*	2040	4230	0.48	1703	4812	0 35	2899	5978	0 48
bench-2b*	1445	3546	0.41	830	3870	0.21	1470	4566	0 32
bench-3*	0	236	0 00	0	343	0.00	0	86	0.00
Total	4408	8992	0 49	4674	12034	0.39	6185	13156	0.47

	1999			2000			totals 1996-2000		
	biasted(l)	moved(2)	ratio(l)/(2)	blasted(l)	moved (2)	ratio(l)/(2)	blasted(1)	moved(2)	ratio (l)/(2)
sector-3"	998	1172	0 85	610	620	0.98	3925	4349	0.90
bench-1 a*	0	1	000	505	582	0.87	572	664	0.86
bench-lb*	594	1417	0.42	323	2415	0.13	3413	7709	0.44
bench-2a*	3168	7294	0 43	3517	7011	0 50	13327	29325	0 45
bench-2b*	536	2277	0 24	180	1197	0 15	4461	15456	0 29
bench-3*	0	199	0 00	0	209	0 00	0	1073	0 00
Total	5296	12360	0.43	5135	12034	0 43	25698	58576	044

* benches belong to sector 2
currently a single bench operation using conventional equipment only.

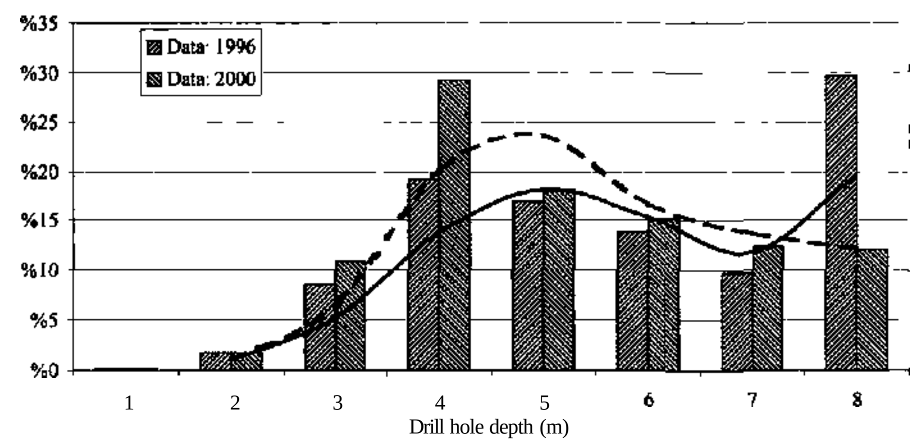
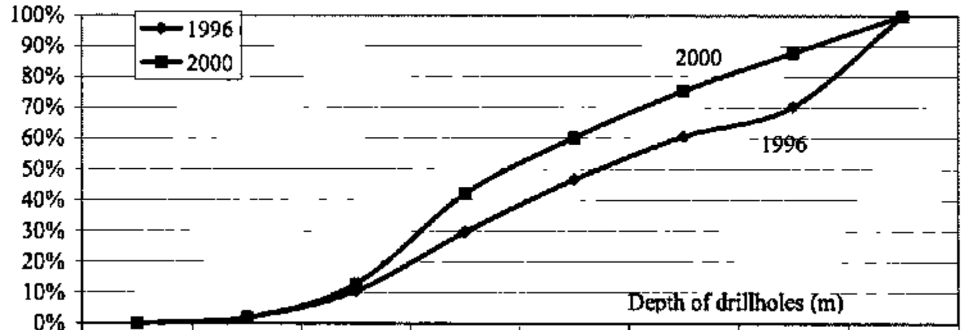


Figure 4. Distribution of drill hole depths

Figure 6 shows the density distributions (histograms) of the total weight of explosives per blast (tons), using data from the same time period. The data indicate that most of the time the blast load ranges from 1 to 4 tons of explosives, although local peaks may be observed in particular months. Again the distribution for the 2000 data is smoother, which results in better predictions and thus better mine planning. Figure 7 presents the corresponding cumulative distribution function for the same data. The results presented in Figures 4 and 6 are interrelated since the decreasing thickness of blasted benches resulted in lower drill depths and lower explosives consumption per blast.

Figure 8 presents an analysis of monthly explosives consumption for the year 2000. It should be noted that although the total consumption is below that of previous years (Figure 2), the trend in the last quarter of 2000 may lead to the conclusion that increased consumption should be expected in 2001.



	1	2	3	4	5	6	7	8
1996	0,2%	1,9%	10,5%	29,7%	46,7%	60,6%	70,3%	100,0%
2000	0,2%	1,9%	12,8%	42,0%	60,2%	75,5%	87,8%	100,0%

Figure 5. Cumulative distribution of drill hole depths.

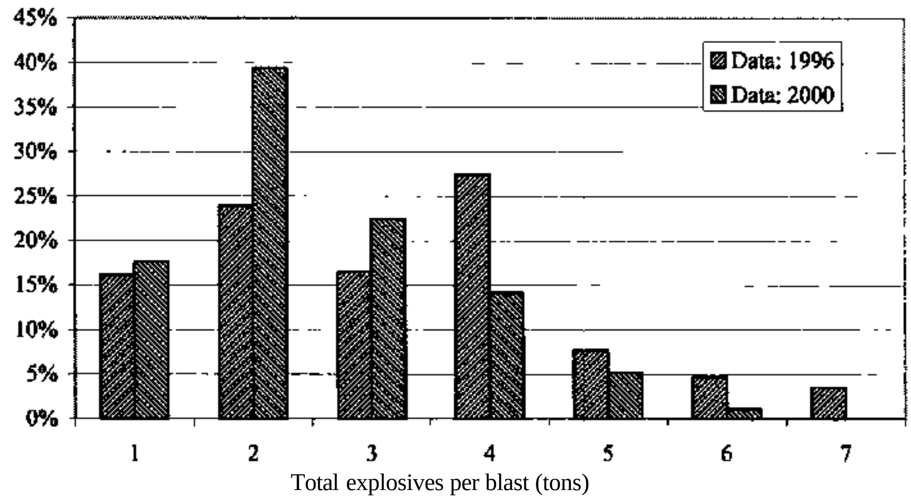


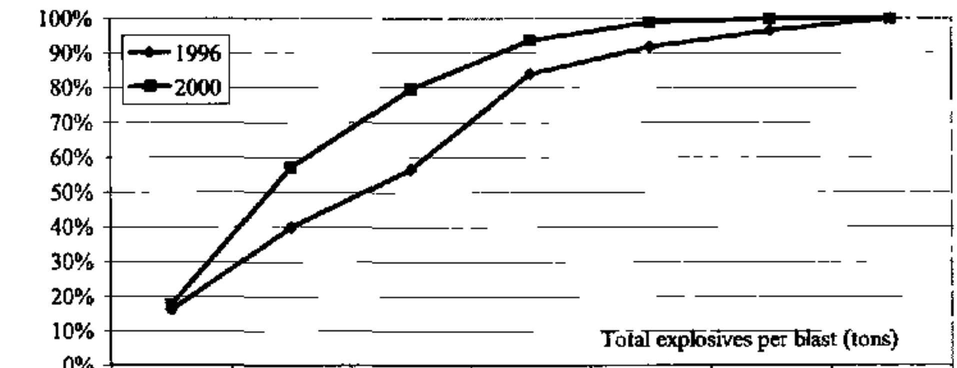
Figure 6. Distribution of total explosives per blast.

This is in accordance with the occurrence of thicker and stronger formations in the currently mined benches. In addition, increased use of water-resistant explosives is evident due to the presence of water in the deeper permeable hard rocks (Figures 8 and 9).

4 SUMMARY AND CONCLUSIONS

Overburden removal operations at the South Field Mine at the Lignite Center of Ptolemais-Amydeon utilize both conventional and continuous excavation techniques. Continuous mining is carried out entirely by the PPC, while conventional mining is carried out by both the PPC and contractors. This paper presented data pertaining to conventional overburden removal operations that require the use of explosives to break up the hard rock formations that occur sporadically within the overburden strata.

It should be noted that blasting conditions are unique due to me variability of the hard rock formations and the fact that hard rock removal has to accommodate the needs and advance rates of the continuous systems that handle the majority of the overburden material. It should also be noted that it is preferable (and more economical) to remove the soft cover of a bench and then blast the hard lenses directly rather than blast the full height of the bench using complicated blast hole loading techmques such as decking



	1	2	3	4	5	6	7
1996	16.2%	40.1%	56 5%	84.0%	91.8%	96 4%	100.0%
2000	17.7%	57.1%	79 5%	93.7%	98.9%	100 0%	100.0%

Figure 7 Cumulative distribution of total explosives per blast

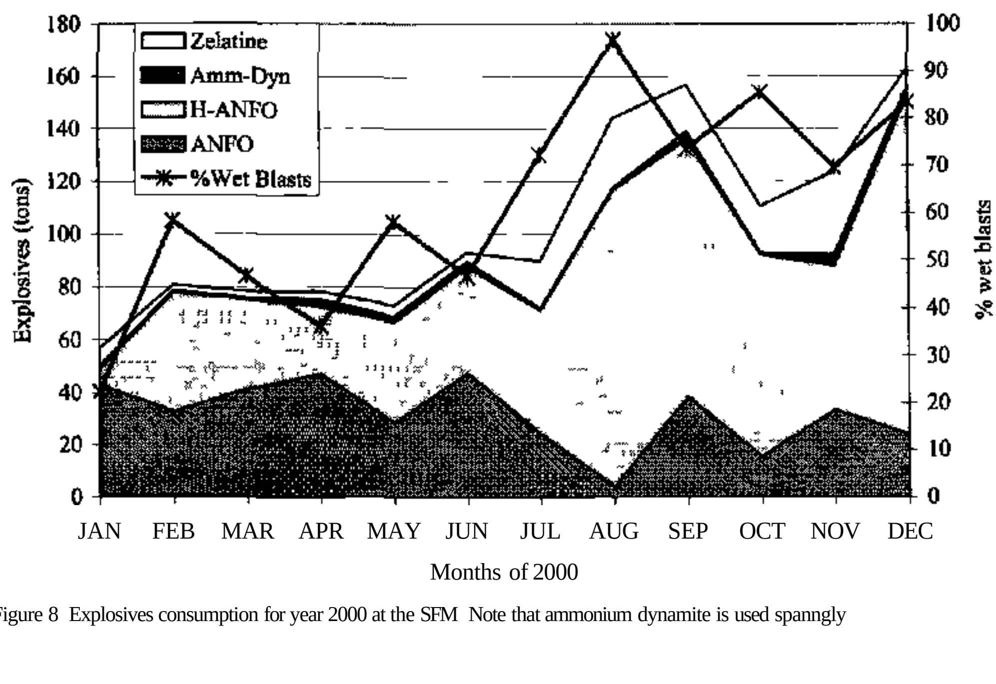


Figure 8 Explosives consumption for year 2000 at the SFM Note that ammonium dynamite is used spanngly

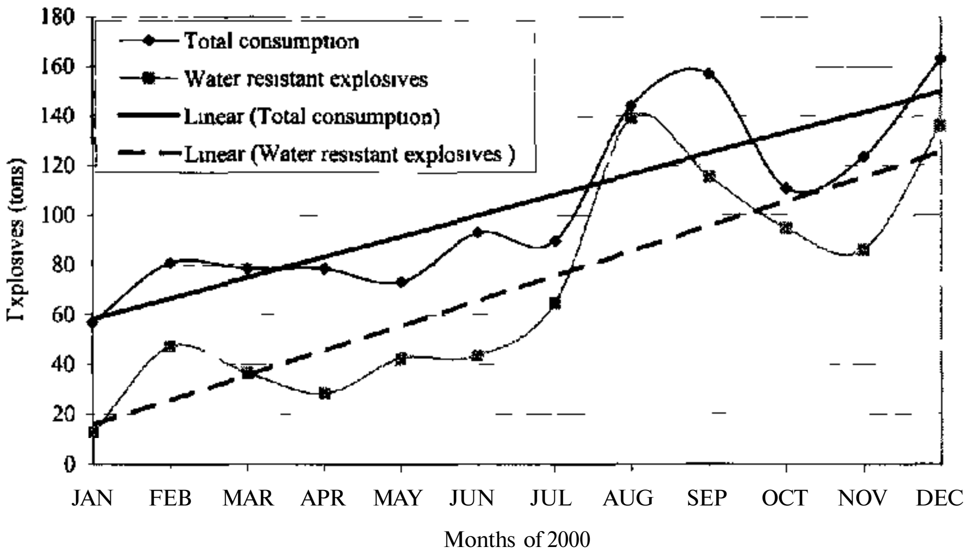


Figure 9 Total explosives consumption and percent of water resistant explosives for year 2000 at the SFM

More specifically, the following statistics were observed

- The annual total explosives consumption ranged from 1650 to 1250 for the last 5 years The projected consumption for the following year{s) is to exceed 1700 tons annually, based on the increased explosives consumption dunng the last quarters of the year 2000
- The total length of blastholes drilled per year is currently m the order of 350km
- In recent years, there has been an increasing need to blast overburden material under wet conditions Currently, the explosive of choice is Heavy ANFO, which is a mixture of ANFO and emulsion explosives, and is produced in situ by special ANFO Mix trucks
- The percentage of water-resistant explosives has also increased m recent years
- The linear trends (projections) for explosives consumption and wet blasts show similar rates (2000 data)
- Forty-four percent (44%) of the material moved by conventional methods needs to be loosened by blasting The remainder is excavated directly from die face using heavy-duty shovels
- In the benches where both the continuous and conventional excavation methods are used (lb, 2a, 2b), forty-five percent (45%) of the overburden material is excavated using conventional methods
- The variability of the overburden material can be established by the variability of the blasted/moved ratios presented for each bench
- Statistical distributions of blast load per blast show that currently, the most common configuration is a 2-ton blast
- Statistical distributions of drill depth per blast show that currently, the most common depth is 4m, which is rather shallow considering that drill diameters are either 7[7/8] or 9 inches and the blasting grid is usually 5x5m

REFERENCES

Agioutantis Z, C Kavoundis, S Bozinis&K. Tsampis, 2000 Assessment of vibration measurements due to blasting of the hard formations at the South Field lignite mine, Ptoiemais, Greece *Proceedings,* 9th International Symposium on Mme Planning & Equipment Selection, Athens, Greece - November 6-9

Agioutantis, Z & C Kavoundis, 1998 Technological enhancements in the drilling and blasting procedures for removing hard formations at the South Field Lignite Mine, Ptoiemais, Greece *Proceedings,* 7th International Symposium on Mine Planning & Equipment Selection, 1998, Calgary, Alberta, pp 173-177

Bozinis S , 2000 Computenzed South Field Mine Blasting Re cords *Unpublished Data* Public Power Corporation

Galetakis, M & Agioutantis Z, 2000 The influence of strategic development options on the long term quality variation of mined lignite the case of the South Field Mine in Ptoiemais, Greece *Proceedings,* 9th International Symposium on Mme Planning & Equipment Selection, Athens, Greece November 6-9

Papageorgiou, C & Z Pakas, 1997 The hard rock removal in the overburden of South Field Lignite Mine of Ptoiemais, Greece *Proceedings,* 2 Konferenz zur Mobilen Gerate techmk, Leipzig, September 17 19