THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

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LEAD-MINES AND WORKS OF THE VIEILLE MONTAGNE ZINC COMPANY.

Nenthead village is situated on Alston Moor, Cumberland, within half-a-mile of the point where the three counties of Cumberland, Durham, and Northumberland meet, and within 5 miles of the source of the River South Tyne. It stands 1,400 feet above sea-level, but within half-a-mile to the east, at Killhope, a height of 2,000 feet is reached, and as the adit-levels enter the hillside at the bottom of the valley, there is nearly 600 feet of strata above the workings.

The mines have been worked by the present owners, the Vieille Montagne Zinc Company, of Belgium, since the year 1896. From 1882 until 1896 they were worked by the Nenthead and Tynedale Company, while previous to the year 1882 they were worked for more than a century by the London Lead Company.

In 1776, the Lords of the Admiralty, who are Lords of the Manor of Alston Moor, with a view to developing the mines, commenced a level, known as Nentforce Level, the starting point of which was Alston, which eventually reached the centre of the Nenthead mining district. Although the level did not reveal many new veins, it has proved invaluable as a means of unwatering the deeper sills of the mines, the outflow being close to Alston railway-station. Shafts have been sunk at different points from the surface to this level. In the past the mines have been worked for lead-ore only, but now nine-tenths of the output consists of zinc-ore or blende and the remaining tenth lead-ore.

The main veins run almost due east and west, and are crossed at frequent intervals by north-and-south veins of more recent origin. The latter are, as a rule, poorly mineralized, but sometimes contain pockets of ore, several good flats having been worked close to the point of intersection. The east-and-west veins usually dip northwards at a gradient of 80 to 90 degrees, the throw in every case being different, varying from 1 foot in some cases to as much as 60 feet in Archer's Vein at the Capelcleugh Mine. Beginning with Brownleyhill Vein, the northernmost in the royalty, and travelling southwards up the valley, it is found that the up-cheek of that vein is the down-cheek of the next (or Gudhamgill) vein, and so on. The veins are widest in the hard strata—limestone, "hazels,"* etc.—pinching out and nearly disappearing in the "plate"† beds; consequently, the Great Limestone, which has an average thickness of 63 feet, has been the most productive stratum in these mines. Unfortunately, it has been to a great extent worked out in past years.

The principal east-and-west veins at present being worked are Brownleyhill, Gudhamgill, Scaleburn, Rampgill, Barney Craig, Middlecleugh North, Middlecleugh, Middlecleugh Second Sun, Longcleugh, Capelcleugh, and Archer's, all being reached by adit-levels that enter the hillside at the bottom of the valley. Barney Craig Vein is also reached by an adit-level from the neighbouring valley of West Allen, Northumberland; but the mine is connected by cross-cuts to Rampgill Level, and all ore is brought out at Nenthead. With the exception of the Gudhamgill, Rampgill, and Barney Craig Veins, where shafts have been sunk and the deeper sills are being worked, all the workings are above water-level.

About 1¼ miles from the entrance to the Rampgill Mine, a shaft, 372 feet deep, has been sunk from the "random" of the level to the Scar Limestone, in order to develop the deeper sills. From the bottom of the shaft a cross-cut of about 300 feet was driven, and then an inclined shaft, 330 feet long (equal to a perpendicular depth of 300 feet), which followed the vein, was sunk with the intention of prospecting the Whin Sill. When the Tyne Bottom Limestone was reached and penetrated, the Whin Sill, which should occur immediately below, was found to be absent, and in its place were a number of thin alternating beds of limestone, hazel, and plate, which, according to the general section, should follow it. Although the Whin Sill has been proved in many places in the neighbourhood, it does not seem to exist in the Nenthead district. In the course of sinking, it was found that the vein had split up into numerous strings, which

* Hazel—a tough mixture of sandstone and shale.

† Plate—shale.

have been prospected by driving in them, several cross-cuts also being driven both on the southern and the northern sides. In the bottom cross-cut it was found that the strings contained mainly carbonate of iron and calcite, and no lead or zinc-ore. The lower part of the Rampgill shaft is now idle and partly full of water, but the Slaty Hazel sill, situated 270 feet down the shaft from the horse-level, is still being worked. Below the horse-level the Quarry Hazel, the Four-Fathoms Limestone, the Nattrass Gill Hazel, and the Slaty Hazel are productive and well mineralized.

The mineral from the workings below the water-level in Rampgill and Barney Craig mines is filled into wagons, run to the Rampgill shaft, and hoisted up to the Rampgill horse-level by a 35-horsepower double-acting winding-engine. It is then, with the mineral from the workings above the horse-level, drawn to the surface, in trains of sometimes as many as twenty-five wagons, by a 12-horsepower single-cylinder petrol-driven locomotive. In the Capelcleugh and Middlecleugh mines the mineral is drawn by horses to the dressing-floor; whilst in the Gudhamgill and Brownleyhill mines, which are situated about half-a-mile down the valley, the mineral is tipped into hoppers, reloaded into wagons, and drawn to the dressing-floor, as required, by a second 12-horsepower single-cylinder petrol-driven locomotive, which (on account of its having to climb a steady incline) draws only about 6 tons of crude ore per journey.

Very little pumping is required, as nearly all the workings are unwatered by the levels, which slope gradually towards the adit: this condition also facilitates the drawing of the loaded trains of mineral. Pumping is necessary in the workings below the Rampgill and Barney Craig adit-levels, the Mammoth system being employed. In this system compressed air is admitted at the bottom of a vertical pipe-line immersed in water, the compressed air rising and carrying with it an ascending column of water. In the Rampgill shaft the operation is carried out in two stages, the first by 2½-inch pipes to a 44,000-gallon tank situated at the Nattrass Gill Hazel, and the second by 4-inch pipes to the adit-level. The height of the first stage is 141 feet, and of the second 131 feet. The provision of the 44,000-gallon tank at the Nattrass Gill Hazel allows of pumping being stopped from 2 p.m. on Saturday until 10 p.m. on Sunday. The system requires no machinery and no attendance, and on an average 5 cubic metres of compressed air is sufficient per minute to pump 155 gallons of water. The same system is used in the Barney Craig sump. All the necessary pumping is carried out while the rock-drills are not working, and, thus, by avoiding simultaneous calls on the compressed air, a satisfactory pressure is maintained.

Drilling is performed partly by hand and partly by means of rock-drills and pneumatic hammers, rock-drills being used for driving forebreasts and in very hard ground. About twenty-five machines are at work, comprising McCulloch, Rand, and Cherson rock-drills; Rex, Leyner-Stoper, and Water Leyner pneumatic hammers, which work on columns: and Flottmann, Thunderbolt, New Century, and Forster pneumatic hammers, which are manual machines. The consumption of compressed air is about 500,000 cubic feet per working day of 16 hours, or nearly 31.000 cubic feet an hour. The drills are sharpened with a Leyner sharpening machine, driven by compressed air.

Until within recent years a McCulloch compressor, which produced 20 cubic metres of air per minute, and five small Schramm compressors, which produced about 35 cubic metres per minute, were used, the former being driven by a 250-horsepower Lancashire boiler and the latter by six Robey boilers. This steam-driven plant, although kept in repair for use in cases of emergency, has been gradually superseded by compressors driven by Pelton wheels, installed at the bottom of two of the shafts, so as to gain fall and pressure. The plant consists of one Schramm compressor producing 6 cubic metres per minute, one Cranston compressor producing 5 cubic metres per minute, one Ingersoll compressor producing 5 cubic metres per minute, and a hydraulic compressor, which is worked as follows:—

Water is obtained from three reservoirs on the hills surrounding Nenthead, containing 16,500,000, 3,750,000, and 2,600,000 gallons respectively. The last-named reservoir is situated in West Allen, and drives the Ingersoll compressor in the Barney Craig mine. The water from the other two reservoirs is conveyed in pipe-lines to the top of the Brewery shaft, which is sunk from the surface, and has a total depth of 328 feet, on the top of which a water-tower about 90 feet high has been erected. The water enters a vertical pipe-line, and reaches the tower by its own effort to find its level. The pipe-line is here connected by a bend to a downfall line, also in the tower, near the top of which line is a system of holes and small internal pipes which admit air. A quantity of air is thus sucked in by the descending column of water, and conveyed to the bottom of the shaft, where is flows into a bell-shaped receptacle, there separating from the water and rising to the top of the bell. The water escapes through an ascending pipe in the shaft to a height of about 200 feet, and creates the back-pressure necessary to compress the air to a pressure of 90 pounds per square inch. The water from this third pipe-line, with its fall of 200 feet, is brought down another pipe-line, and used to drive the Schramm compressor at the bottom of the Brewery shaft, where it finds a natural outlet through Nentforce Level. This hydraulic compressor produces about 13 cubic metres of air for a consumption of 6 cubic metres of water per minute.

The dressing works are situated a short distance from the mines, and have a concentration plant capable of dealing with 200 tons of crude ore per 12 hours' work. The installation, although not altogether satisfactory in every point, is yet perhaps the most complete and up-to-date of its kind in this country, and is constantly undergoing improvements. It was erected during 1909, and commenced working in July, 1910. This type of mill turns the crude ore into a marketable product in one process, the different operations following each other automatically and without interruption. To this effect, the necessary machinery has been placed in one building of five floors, made throughout of strong iron framework and bricks. The ore is hoisted 70 feet to the top floor and there tipped into hoppers. Whilst gravitating from one apparatus to another, the galena and blende are separated from dead rock, gangue, and dirt, and concentrated so that the percentage of lead and zinc is suitable for metallurgical treatment.

For the purpose of describing the process three departments might be distinguished, namely, the hand-picking and coarse-crushing department, the jig department, and the slime-house. In the hand-picking and coarse-crushing department all pieces of about $\frac{3}{4}$ inch cube are first sorted, in order to eliminate as much clean ore and refuse as possible and to avoid unnecessary crushing. Picking takes place on two revolving circular tables, one of which has a central ring shaft, whilst the other runs on wheels driven by gearing. All rock mixed with ore is partly broken by hand, and partly crushed in a Blake-Marsden stone-breaker, the small sizes being reduced in three sets of crushing rolls, 39, 34, and 30 inches in diameter respectively. The material is crushed to about $\frac{1}{2}$ inch cube and then lifted back by a bucket-elevator to the fourth floor, where it joins the original material of about $\frac{3}{4}$ inch cube.

The jig department occupies the first and second floors, and its products are stored in a great number of hoppers standing on the ground floor underneath the jigs. On the floors above the jigs are conical screening trommels of various types, in which eight different sizes of ore, from the coarsest to the finest, are produced, so as to feed every jig with its proper size. Two more very fine sizes are got in hydraulic classifiers, the smallest size washed in the jigs being $\frac{1}{32}$ inch. There are thirty-eight jigs of three, four, and five compartments, eight of which have lateral outlets for coarse grains, whilst the rest discharge their products through the beds and bottoms of the tubs. Four have a knee-lever motion, the others being excentric. They are arranged in three sets or systems, the first serving for the preliminary washing of the material, and the other two, which comprise twenty jigs, for finishing off the intermediate products of that washing. The first washing gives galena, a little zinc and lead middlings (which are stored and dressed up from time to time), two sorts of blende, a great quantity of mixed middlings containing some zinc, and definite refuse. The two auxiliary systems are in connexion with four sets of fine-crushing rolls, two Huntington mills, and a new Hardinge conical pebble-mill, the latter being in course of erection, where the middlings are ground to a sufficient fineness for further jig work.

The slime-house possesses all the machinery necessary for the treatment of the fine material under $\frac{1}{32}$ inch contained in the original ore, and the large amount of fine sands and slimes which are inevitably formed during the crushing, screening, and jigging operations. It is only by repeatedly treating the intermediate products that it is possible to obtain a product of sufficient concentration for the market, and avoid loss in the waste. The material is transported to the slime-house by water and there allowed to settle in large spitzkasten, from which it goes to hydraulic classifiers in order to give every slime-table its appropriate size of feed. There are forty-eight tables of three different types, namely: (1) twenty-two shaking tables covered with linoleum, and provided with wooden riffles, suspended in groups of four on iron supports by means of springs, and on these tables the fine but still palpable sands are washed: (2) ten percussion tables with endless indiarubber belts, erected in a similar way, for washing the finer sands and coarse slimes; and (3) sixteen circular cement-covered revolving tables from 13 to 16 feet in diameter, at various inclinations, which are erected in pairs on a common ring-shaft, and treat the very finest slimes. The slime installations are also divided into a main system, for preliminary washing, and a middling system. The finished galena and blende settle in tanks, which are emptied by hand, and the intermediate products are sent back to the spitzkasten and tables by centrifugal pumps. In close proximity to the slime-house is a smaller slime-treating installation, consisting of six rapid percussion-tables standing on springs, and four rubber vanners.

As a scarcity of water often prevails at Nenthead, the water is recovered after use, and used over and over again. To purify the dirty water, it is pumped into an outside settling spitzkasten of large dimensions, from which the clarified overflow goes back to the jigs and tables. The deposit, which contains an appreciable quantity of mineral, is sent back to the slime-house.

The stones picked from the crude ore, and the refuse separated from it by the jigs, are hoisted by a two-cage lift to the top floor of the building, whence they go to the waste-heap by an aërial ropeway, which, together with the two lifts, is electrically driven.

The marketable products, unless too wet, are also lifted to the top floor and stored in large hoppers, whence the carts are filled that transport them to the railway-station.

The power required for driving the installation amounts to 325 horsepower, and is generated by two superheated steam-engines of 225 horsepower each. These engines are of the locomobile type, that is, the two cylinders of each are placed immediately above the boiler. The boilers are of the fire-tube type and designed to withstand a working pressure of 270 pounds, but are worked at a pressure of about 180 pounds per square inch. The steam is superheated to 570° Fahr. The engines are fitted with feed-heaters and jet-condensers, and the air-pumps are directly driven by a rod from the crank-shafts. The distribution of the steam is by the Lentz poppet valve-gear, which has proved to be of the highest mechanical efficiency. These valves are doubleseated, and arranged horizontally, under the cylinder body, opposite to one another, and are actuated by a cam-shaft, with which they are kept in tight connexion by means of springs. The distributing shaft is directly driven from the excentric. The lubrication of the cylinders is by automatic oil-pumps. The engines give satisfaction in every respect, and are very economical with regard to combustion and evaporation, the power being generated at little more than ¼d. per horsepower-hour, everything included. One engine drives the main plant directly by transmission, and the other a three-phase alternating-current generator of 500 volts and 250 amperes. Several more or less independent installations are driven by separate motors: for instance, the hoists, aërial ropeway, centrifugal pumps, weighing-machines, slime-tables, etc. For lighting purposes, the voltage is transformed down to 120, and utilized for twelve arc and several hundred incandescent lamps.

In winter, the steam from the engines is used in a system of radiated pipes for heating the whole of the dressing plant.