Underground Surveying

By Raymond Shackleford
Posted: September 29, 2000

A primer in coal mine surveying and mapping.

When someone learns that I survey in underground mines, they very often ask, “What's it like to survey underground?” This article will discuss the similarities and differences between surveying in the sunlight and surveying deep underground.

In Alabama, where my coal mining experience has been, the seams are fairly level and range in thickness from around 2' to as much as 15'. If the coal seam or strata is thick enough to stand on, it is usually called high coal; if not, it is called low coal. In the low coal mines, coal is moved by low profile conveyor belts. In transportation areas, the roof is blasted higher than the seam, and at conveyor belt headers and other key locations, rock is removed to provide room to stand and work. The ideal height of a coal seam is around 7', which permits walking upright while being able to reach the roof. Anything much less or much more presents problems for the workers.

One of the first differences a new surveyor underground notices is the fact that all the survey points are overhead. Because of the mud and the constant traffic of mining equipment, it is not practical to set points in the bottom of the seam. Surveys are generally run on the centerline of the mine areas. Points are set by first drilling a small hole in the roof about 3/4" deep, into which a round wooden plug is driven. Then the survey point is marked by driving a metal spad into the plug. A spad looks like a small flat key. It has a round head with a hole through it and a straight shaft with a rounded point. Once the spad has been put on line, a plumb bob cord is threaded through the spad and tied with a slip knot. Distance measurements are made to the cord with a surveyor’s chain or with an EDM. If electronic measurements are made, the prism must be mounted on a special holder to hang it from the spad. In high coal, a 32-ounce bob is used, since the high volume of air moving to the working faces makes it difficult to steady a lighter one. In low coal it is sometimes necessary to use an extremely short bob, since there is so little headroom.

A Survey Day in the Mines

Jim Kilgore preparing to use a right angle prism for setting a drive spad.

Surveyors are used to carrying a lot of stuff. To do their work efficiently they need plumb bobs, prisms and plumbing poles, measuring tapes, paint, flagging, nails, tacks, stakes, hammers, field books, calculators and data collectors, transit, EDM, tripod, radios... Underground mine surveyors need most of the same stuff, but that is only the beginning. Every surveyor underground wears a miner's hardhat and a wide leather belt that holds a self-rescuer to supply oxygen in case of emergency, plus a heavy battery connected by a cable to an electric lamp on the hardhat. Each crew carries a hand brace and drill bits as well as a heavy-duty, battery-powered hand drill. Instead of stakes and hubs, they carry wooden plugs and spads. They also carry a methane detector to avoid setting off an explosion. Since parts of most coal mines are wet, everyone wears 16"-high rubber safety boots. In thin coal seams the miners and surveyors must work on their knees in the mud, so heavy duty knee pads are standard equipment. In high seams the crew must carry a tall step ladder to reach the roof.

Another difference in underground surveys is that there often must be very short sights. In vertical shafts, it is often necessary to have two control points less than 20' apart since the points are transferred down the vertical shaft by wires or optical devices. And mine entries are often driven around 50' apart. Instrument setups are done with utmost care. The transit is leveled under the plumb bob (there is a mark on the top of the instrument), then the scope set on a 90 degree zenith angle. Then the position under the bob is checked again to ensure that there is no eccentricity. The string is hung from the hole through the spad, making sure it is tied so as to hang from the lowest point in the hole.

To obtain longer sights, control surveys are run down the straightest of the mine

entries when possible. Check surveys are run regularly. When a new shaft is constructed, it is possible to make a tie to surveys on the surface. Rough checks can be made at bore holes which are put down for water or power, but since drills can drift, these checks are only approximate. In some mines, azimuths are determined from time to time using north-seeking gyroscopes. These instruments, which can be mounted on a theodolite, can determine azimuths accurate to 10 seconds or so when used by a competent operator. Many mines have vertical shafts for transporting miners and equipment to the work areas and slopes with conveyor belts for bringing the coal out of the mine. Surveys must be made to keep the slopes in alignment, both horizontal and vertical. These slopes are actually rock tunnels. Survey points are often set both in the roof and in the walls of these tunnels. If track is laid for rail haulage, points can sometimes be set in the railroad ties. Surveys down the slope provide a much more accurate transfer of azimuth to the coal seam.

Mine surveyors do not stay in the dark all the time. They also run surveys on the surface, following the directions of the main courses of the mine, for the purpose of locating power lines and staking out drill holes and shafts. Holes are bored to provide electricity close to the working faces of the mine—preferable to using extremely long cables underground. Other holes are drilled for pumping water out of wet areas of the mine and for pumping rock dust into the mine. Because fine coal dust can explode, the exposed coal must be covered with a layer of powdered limestone. This is why all but the active working faces of the mine are white instead of black. The dust is applied with portable blowers and sometimes by hand. The surveys on the surface are tied to a coordinate grid, which may be a state plane grid or a local one set up for the mine. All surveys are plotted on a master mine map, which is updated daily.

Coal Mine Mapping

Attaching a plumb bob string to a spad.

The map of a coal mine looks a great deal like a city map. The portions of the mine where the coal is removed resemble streets and avenues, and the pillars of coal left to support the roof look a little like city blocks. The mined areas are called entries, courses or headings. Some parts of the mine are referred to as tunnels, but these are usually where it's necessary to cut through rock instead of coal. Mines are often five to seven courses across, each being 20' to 24' wide with crosscuts joining the courses at regular intervals. As mining progresses, some of these crosscuts are sealed with walls called brattices. This permits air flow to be directed. Until these walls can be built, the air flow is routed by hanging heavy curtains across crosscuts. One or more air courses carry air to the work faces (intake air courses), while others carry the air back to the surface (return air courses).

There are several methods of extracting coal while maintaining roof support. One is called longwall mining, which uses a giant coal cutter to remove long strips of coal, after which the roof is permitted to cave in the mining area. The percentage of coal recovered is very high, but this method does not lend itself to all mine conditions. Another is room and pillar mining, in which the coal is removed in fairly short parallel entries called rooms, leaving pillars between the rooms. If conditions warrant, some or all of the pillars may be removed as the room section is mined out. These rooms are lined up by setting a spad at the mouth of each room and an additional spad, called a drive spad, in line with the center of the room. Foremen can hang strings from these two spads and use their cap lamps to signal the miners at the coal face and keep the room on line. To avoid setting up the transit at every room spad, the surveyors use a right angle prism suspended from the centerline spad. The transit man can look into the prism and line the drive spad a few feet away at right angles. This requires good coordination between the transit person and the rod person, and expert use of their miner’s lamps.

One of the main entries contains a conveyor belt that moves coal to connecting belts and eventually to the surface. The belt lines must be carefully aligned and leveled to ensure that the coal does not spill as it moves rapidly. The survey crew sets a row of belt spads in the roof above one edge of the belt framework for horizontal alignment. Levels are run on the spads, so grades can be set on the belt framework. Most level measurements in the coal mines are also in the roof, so level notes are reversed from the order used outside—backsights are minus, foresights are plus.

Greg Alexander setting up

in high coal (note 32-ounce plumb bob).

In addition to surveys for keeping the mine entries going in the right directions, the crew must also make regular progress measurements—"as-built" mine surveys. These measurements are used to plot the mine progress on the master mine map. Copies of the map are furnished monthly to regulatory agencies as well as company headquarters. The measurements are also used to compute volumes and tonnages of coal and rock removed for comparison with weight measurements made on the conveyor belts and outside coal stockpiles. The map shows not only the underground workings but also the buildings and other facilities on the surface, as well as boundary and lease lines. If mineral rights are leased, royalty reports are prepared monthly. Features that must be avoided, such as wells, are shown on the map, and the mining plan is laid out to allow adequate clearance. Emergency escape routes are clearly marked, both underground and on the maps. In the event of a mine emergency, management and rescue personnel can use the map to save valuable time—and perhaps lives.

Portion of an underground mine map, c. 1955.

Most construction projects, large or small, begin with surveyors. Before there is a highway through the swamp, the survey crew must first cut lines to show where it will go. The same is true underground. Miners do not wander around aimlessly. The mine plan is carefully designed by the mine engineers. The survey crew then has the responsibility of seeing that the mine continues to go where the plan indicates. And when the map (the only evidence of mining that most people see) is made, every detail is the result of the work of the underground surveyor.