DIRECTIONAL DRILLING TECHNOLOGY

1. Overview of Directional Drilling Technology

While the use of directional (or horizontal) drilling technology has increased dramatically since the mid-1980's, the technology itself dates back to 1891, when the first patent was granted for equipment to place a horizontal hole from a vertical well. In 1929, the first truly horizontal wells were drilled at Texon, Texas and many horizontal wells were drilled in the USSR and China during the 1950's and 1960's, with limited success. Weakening of oil prices, coupled with the need to reduce finding costs and the development of new downhole devices, resurrected horizontal drilling technology in the late 1970's and early 1980's.

A directionally drilled well is defined as a well bore that intersects a potentially productive formation and does not intentionally exit the formation for the remaining footage drilled. Generally, this means that the well is spudded like a conventional vertical well, and at a predetermined "kick-off" point (KOP), the well is deviated from the vertical so that the well bore enters the formation roughly parallel to the bedding plane. In addition to directionally drilled wells from the surface, some mine operators drill directional wells from within the mine working for degasification and geological control. Currently, there are six different techniques available for drilling horizontal holes, as shown in Figure 1 and outlined in Table 1.

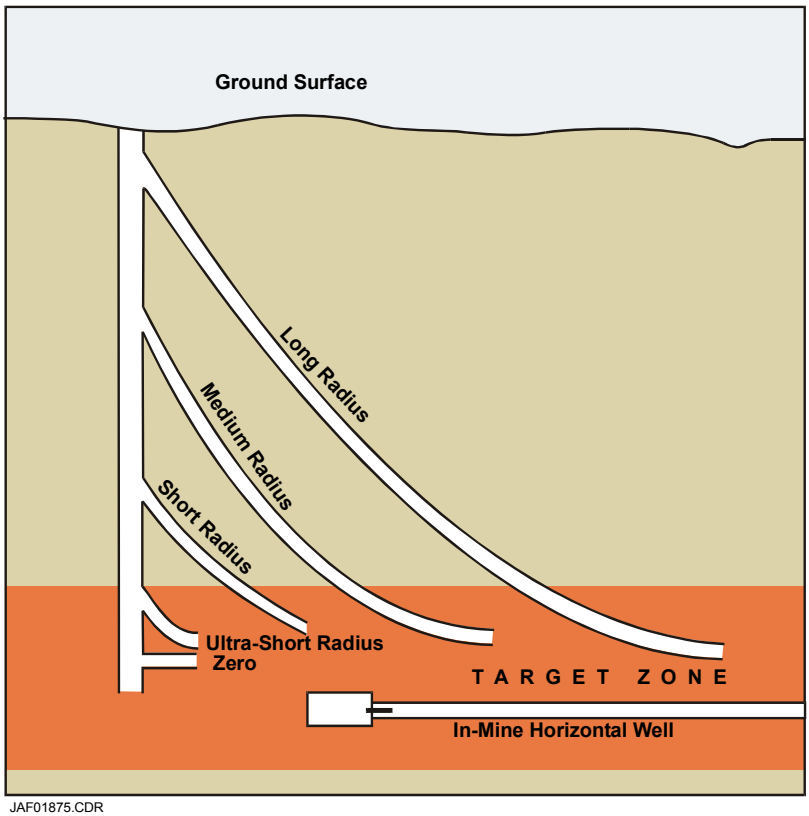

Figure 1. Classification of Directional Wells

Table 1
Classification of Directional Wells

Type Radius	Radius (Feet)	Achievable Lateral Length (Feet)	Method
Zero	0	10	Telescopic probe with hydraulic jet
Ultra-Short	0.5-5.0	200	Coiled tubing with hydraulic jet
Short	35-45	1,500	Curved drilling guide with flexible drill pipe; entire string rotated from surface
Medium	300-500	1,500	Steerable mud motor used with compressive drill pipe; conventional drilling technology can also be used
Long	1,800-2,800	1,500 +	Conventional directional drilling equipment used; very long curve length of 2,800 to 4,400 feet needed to be drilled before achieving horizontal
In-Mine	N/A	5,000	Uses underground drilling rigs with steerable motors and position systems to achieve long, in-seam boreholes

Directional drilling for coalbed degasification is an outgrowth of the techniques developed for degasification through the use of in-mine horizontal holes and surface vertical, stimulated wells ("conventional" CBM wells) using modified oilfield technology. In-mine horizontal holes have the advantage of relatively low drilling costs and the ability to intersect the coalbed cleat or fracture system at right angles to the dominant fracture direction. However, in-mine drilling requires underground access to the coal and facilities that often interfere with the mining cycle (Diamond and Oyler, 1986). Additionally, the requirement of access to the coal can limit the value of the horizontal degasification holes, because of the limited time and/or distance they can be drilled ahead of mining. Generally, horizontal wells only produce for a three to six-month period before being mined through.

The various difficulties associated with degasifying coal seams via in-mine drainage horizontal wells led the industry to the use of hydraulically fractured vertical wells drilled from the surface to degasify the coal seam in advance of mining. At first, many mining companies expressed concern that the hydraulic fracturing process would damage the integrity of the mine roof, thus creating hazardous mining conditions. These fears were largely put to rest after the publication of a U.S. Bureau of Mines Report (RI 9083) which found no significant roof damage in 22 mined-through stimulations.

The concept of directionally drilled degasification holes has been considered as a means of combining the best elements of vertical boreholes and underground horizontal drilling techniques.

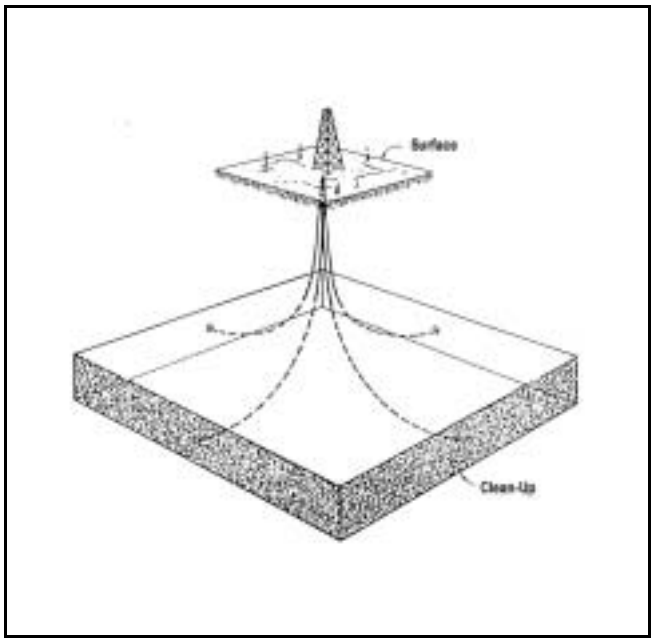

Figure 2: Schematic Diagram of a Directionally Drilled Pre-Mine Degasification.

From a single surface site, a vertical or near-vertical well could be progressively deviated to intersect a coalbed horizontally. Several horizontal gas collection holes could then be sidetracked from the original well bore into the coalbed. The drill rig could be oriented in several other directions on the same surface site, where a succession of directional degasification holes could be drilled. The cost of site preparation and production facilities would be significantly reduced by having the entire gas flow from a large degasification area centralized at one location (Figure 2).

Thus, directional drilling would eliminate the need for underground gas piping systems, would make entry into mines unnecessary, and could degasify large areas of coal far ahead of mining. The directional degasification hole could be used at sites where in-mine horizontal or vertical holes are not feasible and at sites that are unsatisfactory for other types of methane drainage (Diamond and Oyler, 1986).

2. Current Status and Research Projects

2.1 Surface Directional Wells

To date, there are limited published data on attempts at using directional wells drilled from the surface to produce gas from coal. CDX Gas, LLC is currently conducting a directional drilling project at the Pinnacle Mine in West Virginia. The project targets the Pocahontas #3 and #4 coalbeds. Reported production in 2000 from ten wells was 884 million cubic feet (MMcf).

Consol Energy, with support from the U.S. Department of Energy (DOE), will be conducting a pioneering pilot project in northern West Virginia that combines directional drilling technology with enhanced methane recovery methods via CO_2 injection. Consol will drill deviated slant wells with multi-laterals from the surface and will inject CO_2 into the Pittsburgh coal seam after producing methane from the seam for about nine months. The project will monitor the enhanced recovery for a two-year period.

While there is a general lack of published data on current directional drilling projects in coalbeds, several projects were conducted in the 1980's that provide some indication of the potential of this technique:

- **Upper Freeport Coal**. A 3-inch pilot degasification hole, sponsored by the USBM, was drilled to a near-horizontal position in the Upper Freeport coal horizon in Greene County, Pennsylvania.

- **Pittsburgh Coalbed**. Another attempt at using horizontal drilling technology for degasification in advance of mining was made by the USBM in the Pittsburgh coalbed in Greene County, Pennsylvania. In this project, a 3-inch pilot hole was drilled to a vertical depth of 1,000 feet with a total footage of 1,652 feet and a deviation of 5^{o} to 6^{o} per 100 feet.

- **Cameo Coal Group**. In 1986, the Gas Research Institute sponsored a short-radius horizontal drilling project in a deeply buried coal seam, the Cameo "D" seam, in the Piceance basin of Colorado. The well was drilled to a depth of 5,645 feet and a whipstock was set to kick-off the radial portion of the hole.

- **Hanna Coal Seam**. DOE funded a medium radius drilling project at the Rocky Mountain No. 1 site in the Hanna Basin, Wyoming in 1987. In this project, three horizontal wells were successfully drilled into the Hanna coal seam.

2.2 In-Mine Horizontal Wells

One of the biggest advances in CMM recovery has been the increased use of in-mine drilling techniques. The ability to accurately steer boreholes as long as 5,000 feet in advance of the mine face is the result of steerable motors coupled with precision borehole survey systems, both technologies developed during the 1980's.

In-mine directional drilling systems improve efficiency and lower costs by enabling fewer wells to contact the same quantity coal. For example, instead of having to drill a series of relatively short horizontal wells across the width of a longwall panel, several long holes can be drilled down the length of the panel to achieve the same degasification effect. Studies have shown that horizontal wells in a long wall panel can reduce methane levels in the panel by up to 50% within a six to nine month period.

Drilling fewer wells also reduces the amount of time required for inter-hole moves and allows for fewer gas gathering lines within the mine workings. Producing the gas via in-mine techniques can therefore improve project economics and minimize environmental impacts.