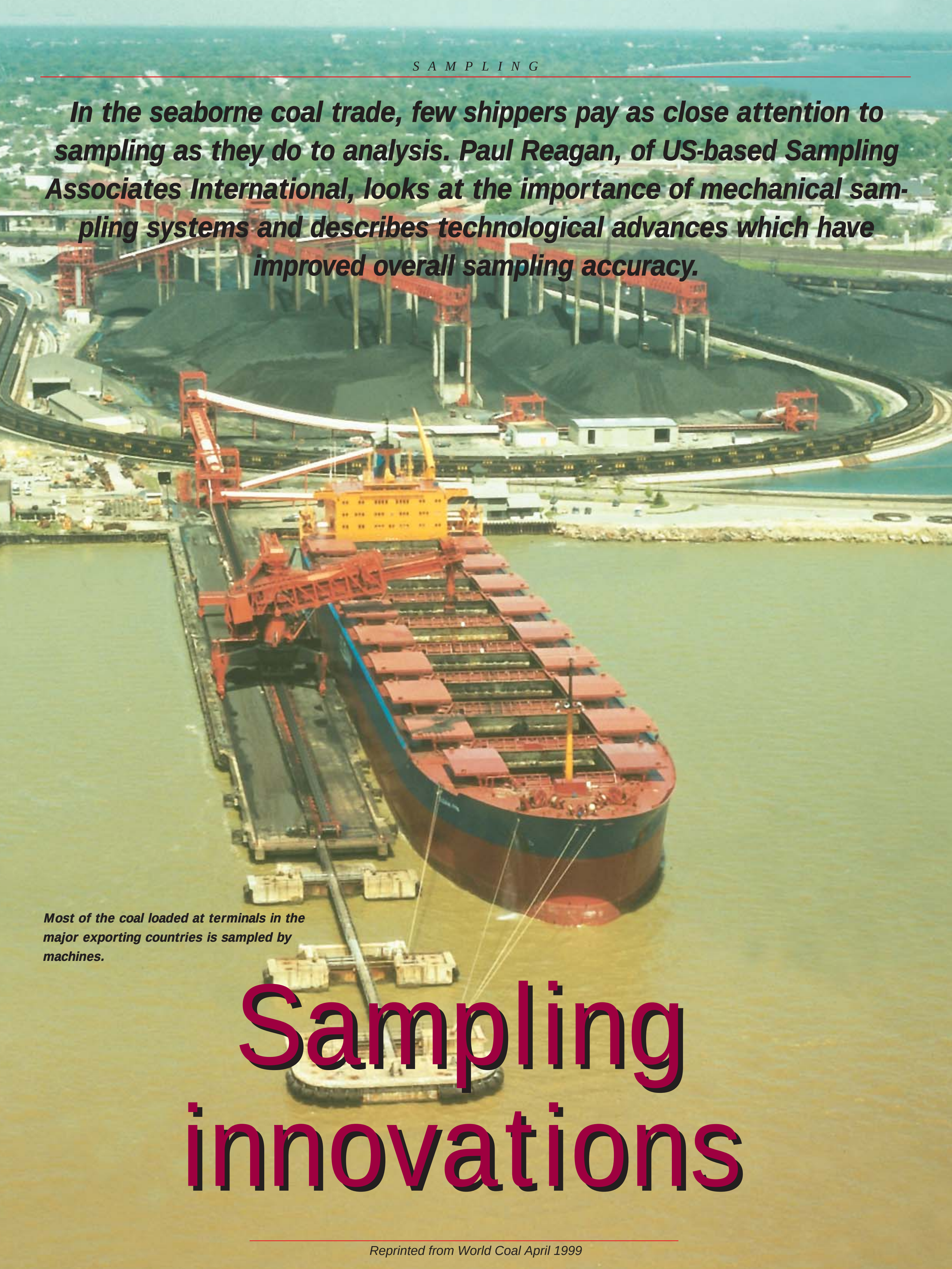
In the seaborne coal trade, few shippers pay as close attention to sampling as they do to analysis. Paul Reagan, of US-based Sampling Associates International, looks at the importance of mechanical sampling systems and describes technological advances which have improved overall sampling accuracy.



Most of the coal loaded at terminals in the major exporting countries is sampled by machines.

Sampling innovations

When money changes hands in the sea borne coal trade, the amount is determined by the sampling and analysis of the cargo – most frequently as the coal is being loaded. While the analytical results are used to determine the amount of money that changes hands, most technical experts agree that sampling is the most critical part of the process. Few coal shippers pay as close attention to the sampling as they do to the analysis.

It is an accepted norm among most sampling industry experts that 80 per cent of the errors in test results are attributable to the sampling (with 20 per cent to the analysis and preparation – figure 1). The best laboratory in the world is of little use if the sample was collected improperly. As a result, good sampling practice is essential.

Most of the coal loaded at terminals in the major exporting countries is sampled by machines. While manual sampling is still performed in many places, at the large exporting terminals it is rare. The preferred method for collecting samples is through the use of mechanical sampling systems.

Table 1. Capturing the correct particle size distribution in the sample

The important chemical properties of coal (moisture, ash, sulfur, BTU) are not distributed equally in the particles of different sizes.

Example

1. A consignment of steam coal is analysed (14.3% ash, 12,857 BTU)
2. Separate analyses of the different sized particles show:

Size (mm)	% In consignment	Dry ash	Dry BTU
+50	6%	12.1%	13,185
50x25	24%	12.6%	13,110
25x12.5	20%	13.3%	13,005
12.5x6.3	22%	14.8%	12,780
6.3x0	28%	16.5%	12,585
	100%	14.3%	12,857

Figure 1. Errors attributable to sampling and analysis.

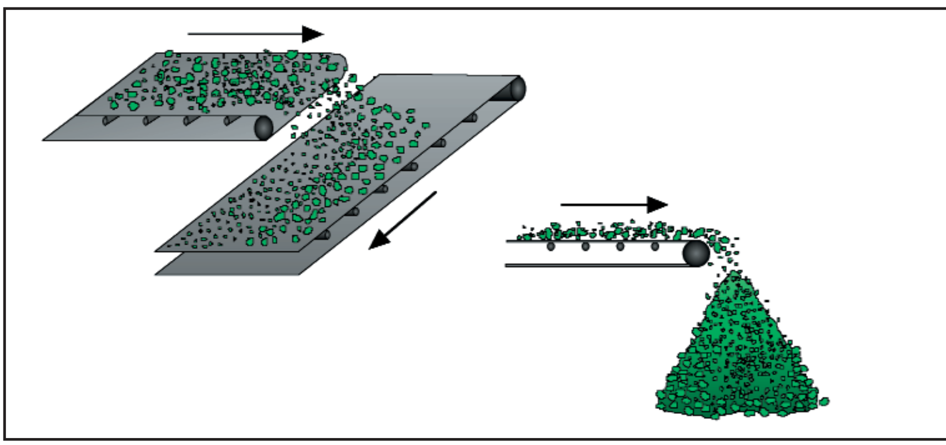


Figure 2. Segregation of coal pieces by size during transportation.

Mechanical sampling

To achieve sampling accuracy, it is important to have the ability to obtain and process individual sample increments that correctly represent the true characteristics of the material being sampled. A sample increment is the amount of coal that is collected by one action of the sampling device. For each sample analysed, many increments need to be collected and processed together. The number and mass of increments are spelled out in the sampling standards. Both ISO and ASTM sampling standards recognise that the most accurate way to sample coal is by obtaining increments that consist of full cross sections of the coal while it is being moved by conveyor.

A full cross section in each increment is required because the important chemical properties of coal (such as ash and Btu) are not homogeneously distributed in the particles of different sizes. In other words, the smaller particles in a coal consignment (0mm x 6.3mm) often contain different ash and Btu than the larger particles in the same consignment. A typical example can be found in table 1 which shows the analysis results of a steam coal cargo from a single source mine.

The ash is much higher and, consequently, the Btu lower in the smaller particles in this particular coal. This variance in the distribution of chemical properties between different size fragments means that the essential challenge of sampling is to duplicate in the collected sample the size distribution that exists in the consignment. This is not so easy to do. Coal is notorious for segregating by size particles when handled: fines will segregate from the larger pieces when the coal is moving on a conveyor, when transferred from one conveyor to another, when stacked in a stockpile and when transported in rail wagons (figure 2).

If the size distribution in a collected sample does not match the distribution in the consignment, then the sample will produce an erroneous test result. In the example in table 1, too many fines in the sample leads to incorrectly higher ash and lower Btu, while too few fines leads to the opposite. In either case, the sample will be inaccurate if the size distribution in a collected sample does not match the distribution in the consignment. Sampling must therefore overcome the tendency of coal to segregate by particle size. The best way to be sure of this is to stop the conveyor belt at regular intervals and take a sample consisting of a complete cross section of the coal. The cross section removes the proper proportion of sized coal and fines regardless of any segregation.

Since repeatedly stopping large conveyor belts loaded with coal is not practical, then cross section sample increments must be taken while the conveyor belt is moving. The only way to do this is to use a machine – a mechanical sampling system.

Two types of sampling systems

There are two basic types of mechanical sampling systems. The main difference between the two systems is the location where the primary increment is collected. The first type collects the primary increment by passing its collection device (primary cutter) from a falling stream of coal at a transfer point between two conveyor belts. This type is called a cross stream cutter (figure 3). The second type collects the primary increment from the coal as it lies on a moving conveyor belt. Essentially, the primary cutter rotates through the coal and sweeps the cross section off. This type of sampler is called a cross belt (or a sweep arm) sampler (figure 4).

Both types of system include sub-systems of other components that process the coal, essentially duplicating the reduction (crushing) and division (riffling) of bulk samples that would take place at the laboratory. Both systems produce a sample that represents the consignment but is small enough that the subsequent laboratory preparation prior to analysis is kept to a minimum. All coal from the primary increments that is not sent to the laboratory (called the reject) is mechanically placed back onto the moving conveyor belt and, in this way, an enormous amount of physical handling of the samples is eliminated.

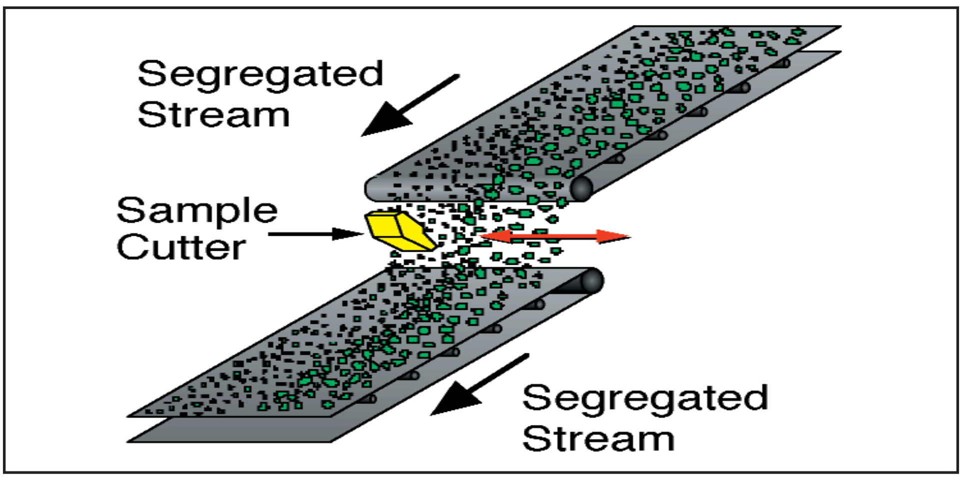


Figure 3. Sample collection at a transfer point between two conveyor belts.

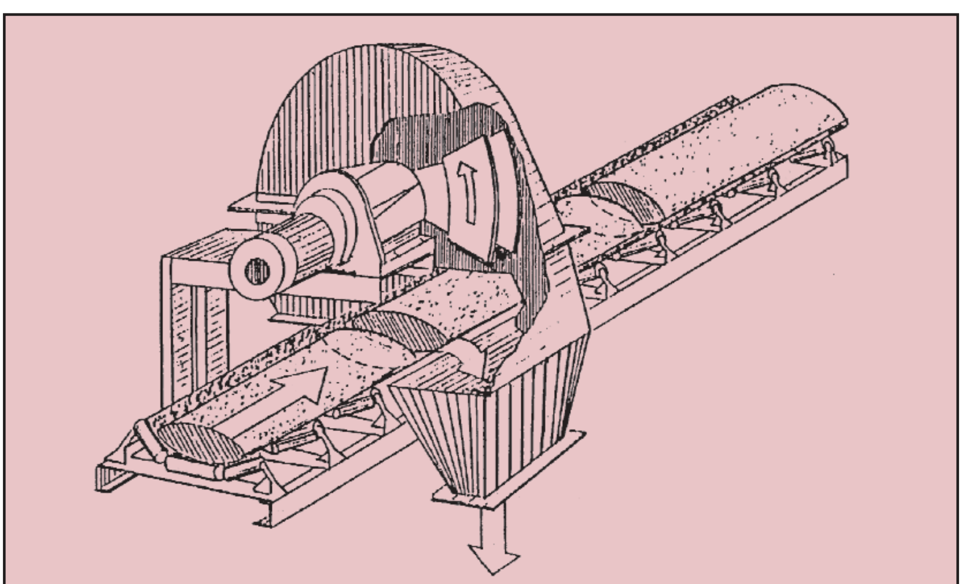


Figure 4. Cross belt or sweep arm sampler.

There is, however, a significant difference between the number and size of the components on cross stream cutters and cross belt cutter systems required to perform the processing. While the size of primary increment is always a function of the tonnes per hour rate of the loading system, cross stream cutters usually take much larger primary increments than cross belt systems.

The cross stream cutter collects its sample increments in a plane parallel to material flow. This orientation adds a factor of 'time in flow' to the cross stream increment mass. When combined with cutter speed limitations recommended by ASTM & ISO for the cross stream cutter, the result is a primary increment mass of four to six times that of a comparable cross belt systems on the same conveyor. On high capacity conveyors, cross stream primary increments of between 300kg and 1000kg are commonplace. Alternatively, the cross belt cutter's orientation is perpendicular to the material flow and it faces no restrictions on cutter speed. On the same high capacity conveyors, cross belt primary increment would be between 50kg and 200kg.

With substantially more primary increment material to process, the 'downstream' or sub-system components of cross stream systems are usually much larger in size, complexity and number, with three to four stages of sample division typically required to achieve a final sample. Cross belt systems typically accomplish the same task in two stages. The resulting difference in system size is dramatic and understandably influences their comparable costs.

Cross belt samplers also enjoy a logistical advantage in location and accessibility. All they need for installation is sufficient room for the primary sampler at a point along the length of a conveyor belt and the downstream processing components can be located for easy access at grade level. Retro-fit installation on existing conveyors is easy, economical and commonplace. Cross stream samplers must always be located at the end of the conveyor belt and they additionally require sufficient height to accommodate the larger number of downstream processing components. As such, the cross stream system is typically engineered at the same time that the conveyor belt system (with the needed transfer point) is designed and retro-fit installations are rare.

Despite these advantages, cross belt samplers were slow to gain widespread acceptance for years after their introduction. However, technological advances have now overcome this resistance and cross belt samplers have become so popular in the US that the installation of cross stream cutter sampling systems is becoming extremely rare – even at new terminals with the opportunity to design the needed transfer point.

Innovation in mechanical sampling systems

Sampling systems in the latter part of the 1990s are very different from the sampling systems of the early 1980s – the time when the widespread use of mechanical sampling started. Many of the sampling systems in use today were installed many years ago and although the challenges of sampling and processing coal samples have not changed, the engineering and technology has certainly advanced. Many of these advances can be retrofitted into older sampling systems.

Areas of innovation

The full cross section

The necessity to obtain a full cross section of the coal in each increment collected is well satisfied by a cross stream cutter but at the cost of a very large primary increment and more robust processing equipment. The cross belt samplers reduce the mass of the sample increment but their ability to collect a full cross section was slow to be accepted. The initial resistance to cross belt samplers was fuelled by doubt regarding their ability to collect a representative primary increment. One of the most important advances in mechanical sampling overall has been the proven ability of cross belt samplers to collect representative primary increments.

There are two special challenges for a cross belt primary sampler to extract a full cross section. Firstly, in order to collect the fines that tend to move closest to the conveyor belt, the primary sampler needs to touch the belt. Understandably, this point of impact is an area of high wear and needs to be constantly adjusted to prevent a gap developing between the edge of the sampling mechanism and the conveyor belt.

The second challenge is that most conveyor belts are not configured in a perfect arc. The support idlers usually cause the belt to take on the shape of the idler racks (figure 5) and without some modifications, the coal in the junction areas between the corners of the belt cannot be collected.

This problem is exacerbated if the location of the conveyor idlers is far apart at the location of the primary sampler. If the idlers are far apart, the belt can sag between them, moving the belt away from the primary sampler and potentially allowing part of the increment to escape under the sampling device.

In the newest sampling systems, the full cross section problem has been virtually eliminated. Most new systems have a set of special impact idlers, or even a full impact 'saddle' placed under the conveyor belt at the point of impact. This eliminates any effects of conveyor belt sag. In addition, special idlers of a declining degree of angle are often added before and after the point of impact to gradually reshape the contour of the belt to eliminate the 'corners'. In an innovative approach, one manufacturer has developed a patented support mechanism that pneumatically lifts the belt into a perfect contour shape for the brief time the primary increment is collected (figure 6)

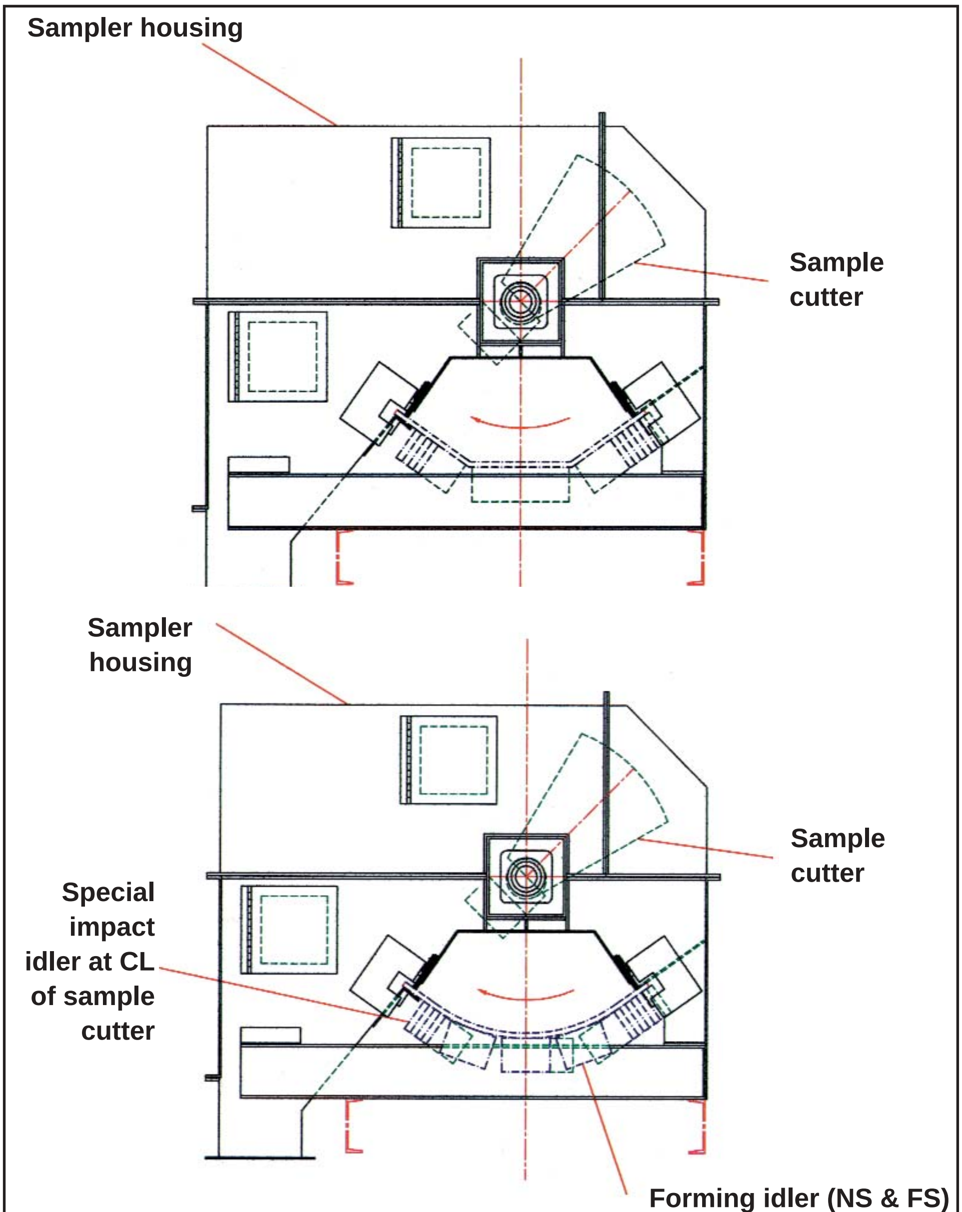


Figure 5. Comparison of sampling stations; above, the unmodified station and below a sampling station fitted with special impact idlers to generate a perfect belt contour.

Crushing the coal

After collecting a full cross section primary increment, the next major challenge of mechanical sampling systems is to crush those increments to a topsize suitable for the laboratory (so that further crushing in the laboratory can be minimised) without influencing their moisture content. To accomplish this goal, the crusher needs to be free of plugging and easy to inspect, clean and repair.

There are two types of crushers in mechanical sampling systems for coal. The first is a hammer mill crusher which employs high rpm internal rotors that rotate hammers and crush the coal by impact – driving it through a barrier (either a screen or a series of closely spaced bars). As a result, these crushers are very effective at producing coal of a low enough topsize (4 mesh or lower) that eliminates further crushing at the laboratory.

The downside of some hammer mill crusher designs is that the high rpm of the crushing hammers can create an air pressure differential in the upper and lower parts of the crusher and cause airflow. When uncontrolled, this airflow can lead to moisture loss in the sample. Another problem with hammer mill crushers is wear. Without proper alloys in their internal parts, they can wear quickly. The most important variable affecting the crusher performance is the size of the gap between the tip of the crushing hammer and the screen (or bars) against which the coal is crushed. As the hammers and screen wear, the gap grows, crusher efficiency declines and can lead to increased plugging.

The second type of crusher is a roll crusher. These crushers utilise a very slow rpm cylinder (or 'roll') which crushes the coal against a fixed plate or another roller that is also rotating slowly. Roll crushers have some advantages. The first is the slow rotation of the rolls which produces lower airflow and lessens the potential moisture loss. Secondly, they tend to wear more slowly and, most importantly, as wear does occur, they can be adjusted to keep the crushing gap consistent. Finally, they can be less prone to plugging with fine and sticky coals.

One downside of the roll crusher is that, for a given size, they have less crushing capacity than a hammer mill. Another downside of roll crushers tends to be in efficiency. The coal is not being forced through a barrier like a screen, therefore most roll crushers are unable to produce a product with a topsize much less than 3/8" and an extra off-line crushing stage is required in sample preparation at the laboratory. Not only is this expensive and time consuming, but the extra handling and crushing exposes the sample to moisture loss.

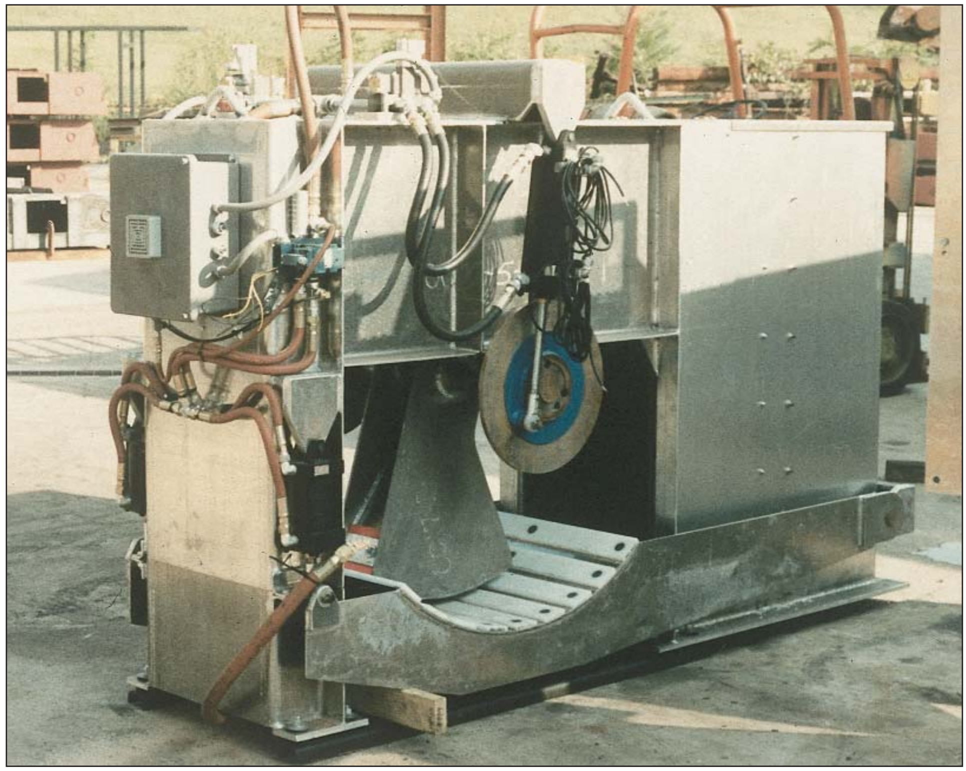


Figure 6. Support mechanism for shaping the conveyor belt to the required contour for precise sampling.

The larger top size of the coal in the sample often requires additional crushing and handling at the laboratory and this extra handling can increase preparation errors and expose the sample to moisture loss. Hammer mill proponents would argue that it is imperative to avoid this extra handling at the laboratory. Roll crusher advocates would counter that it is much more important to avoid the downtime associated with frequent crusher plugging. Weighing the pros and cons of the two different types of crushers often comes down to the topsize and moisture content of the coals that need to be crushed. Wet and fine coals cause problems for any crusher, but roll crushers tend to have a better record with them. However, avoiding the further handling and crushing at the laboratory is important and so a well designed hammer mill crusher has a distinct advantage.

Advances in crusher design

There have been a number of important advances in crusher equipment, particularly hammer mills. The first is reduced wear from hammers made of hardened hybrid alloys and the second is improved access to the crushers for cleaning and replacement of worn parts.

One of the long standing problems with mechanical sampling systems has been the fact that access to the components for cleaning and maintenance has been poor, especially in the crushers. Given the wear and plugging described earlier, this poor access has caused problems for sampling system operators. This key weakness has been addressed in recent crusher designs.

The McLanahan Corporation has recently introduced a crusher that has rapidly gained popularity due to its ease of access (figure 7). One of the most advanced crushers is one produced by JB Long Company of Knoxville, Tennessee, US. It is a hammer mill but it has been engineered with a special housing design and a heavy emphasis on air seals so that it can operate at very high rpm's without moisture loss.

The high rpm's allow it to obtain the same topsize in the coal but with larger openings in the screen plate. These larger openings greatly increase the open area of the screen and dramatically reduce the tendency to plug. In addition, a special mechanical wiping arm has been added to the crusher inlet chute (a notorious location for plugging) to periodically remove any coal buildup in this sensitive location. The addition of an optional hydraulic lift-

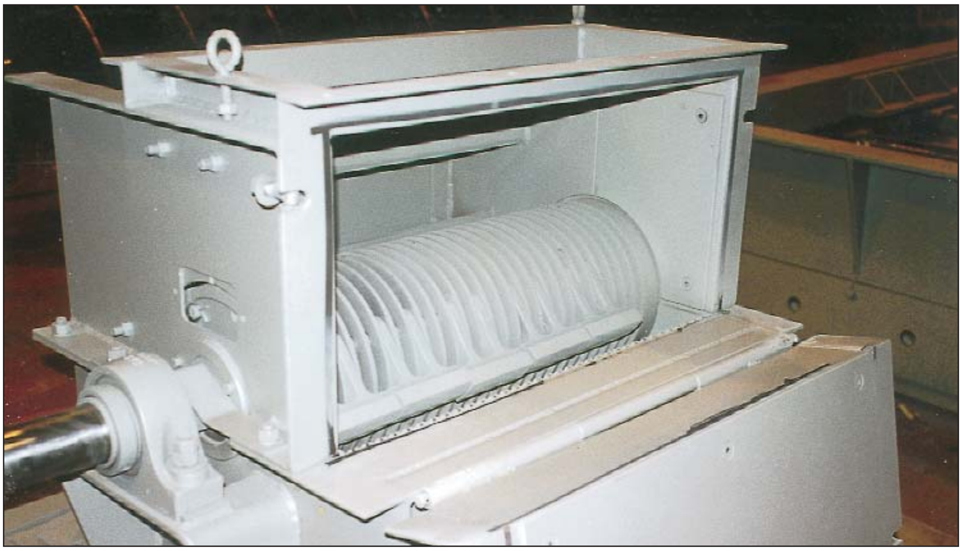


Figure 7. Mclanahan Corp. crusher showing ease of access.

ing mechanism to open the crusher easily has increased the popularity and effectiveness of this machine.

Command and control

There is no doubt that the introduction of the programmable logic controller (PLC) into mechanical sampling systems has been a major advance. The PLC is simply a small computer which controls the sampling system components through software programs. Sampling system components need to be integrated to run properly and smoothly. Start up / shut down sequences, fault alarms, and the proper timing and operation of different functions all need to be carefully controlled. In older systems, this would be hard wired utilising a massive array of wires, timers, relays and motor starters. Today, most of this can be replaced by the silicon chip.

In addition to simplifying the electrical portion of a mechanical sampling system, the PLC has provided several important capabilities. The main one is the ability of the PLC to collect and transmit data regarding the sampling operations. Key data that used to be recorded by hand is now stored in the PLC and can be printed out and manipulated to produce sampling reports and quality control data, such as date / time operation data, number of primary cuts and number of secondary cuts. When combined with a scale for determining the sample mass, statistical process control charts can be produced automatically – further enhancing operations.

A second major advantage of PLC controls is the ease of trouble shooting problems and malfunctions. The older (non PLC) systems would often require painstaking searches for the source of a problem with a voltage meter. With the use of the LED lights on the I / O modules, the problem location time on PLC controlled systems is vastly reduced. PLC systems can be programmed to specifically identify the source of failure and send that message to the operator. The inclusion of a modem allows for the diagnosis of problems over telephone lines. One manufacturer includes an option where the PLC automatically places a telephone call to a pager carried by the technician to notify them when system problems occur and their source.

The early sampling systems were not designed with the human operator in mind. Newer systems have improved conditions for operators.

A final word on maintenance

The sampling of coal with machines is commonly referred to as ‘automatic sampling’. While many of the innovations discussed have moved the industry closer to the goal of being fully automatic, these systems are still machines and need proper care. Any purchaser of an ‘automatic’ system that overlooks routine inspection, cleaning and maintenance will be disappointed.

Sampling systems, like any machine, need good preventive maintenance, especially on the high wear items. When multiple sources of coal are sampled, they need frequent and thorough cleaning and they also need rapid resolution of problems and malfunctions. The result of a sampling system that is poorly cared for is not just reduced output or inefficient operation, but erroneous samples. In such a case, the laboratory can be perfect but they will get the wrong answer.