Australia has abundant supplies of coal, mainly from Permian measures in the eastern part of the country. Coal production from Australian coal mines is predominantly for the export market. Consequently, coal quality must adhere to relatively tight specifications and therefore a very high proportion of coal production is washed.

An important factor in evaluating a coal resource is to consider practical implications of washing by carrying out a process study. The process study will consider a range of options with the aim of arriving at a fit-for-purpose plant design. Desired product specification and the resource sizing and washability will enable definition of the optimum washing process. The optimum process is not always selected, as other issues, such as the life of the mine, capital expenditure and payback period also need to be considered from a whole project perspective. Issues such as included dilution and seam scheduling are also important when designing a plant.

Wes Mackinnon and Andrew Swanson, QCC Resources Pty Ltd, Australia, detail the coal preparation techniques typically employed in the Australian coal industry.
Process technology
A modern Australian coal preparation plant typically consists of wet screening, dense medium processing of the coarse material (nominally +2 mm or +0.5 mm wedge wire [ww]), water-based processing of deslimed fines and froth flotation of all, or part, of the fine coal fraction. Beyond this basic framework, a number of options exist.

Screening
Raw coal is divided into coarse and fine fractions by wet screening. The only alternative to wet screening is dry screening, which is sometimes used where a proportion of the feed can be bypassed directly to product. Although recent developments suggest dry screening may be undertaken at reasonable efficiency down to about 5 mm, this is only applicable for low moisture material (less than 4% surface moisture) and is not particularly relevant to Australian operations.

In the past, sieve bend / low head screen combinations were used to deslime at about 0.5 mm ww. However, there is now almost universal acceptance of the higher capacity, multi-slope (banana) screens with screen apertures of 1 – 2 mm ww being typical. Sieve bends are finding application for classification duties at about 0.25 – 0.5 mm, often in conjunction with hydrocyclones. Fine-aperture high-frequency vibrating screens are often used for the dewatering of sand-sized fine reject and, in some instances, for preliminary dewatering of fine product coal.

Wet beneficiation
These processes use water or other separating media to sort raw coal into products by means of a density separation. It is well proven that dense medium processing will offer a sharper (more efficient) separation relative to a water only plant, but the impact of this needs to be related back to the coal washability, the cut-point of separation and the presence of near gravity material around this cut-point. For a simple separation with little near gravity material, the metallurgical improvement offered by a dense medium process may be minimal, even negligible. However, it should be noted that the recent move towards dense medium plants becoming industry standard has resulted in water-based plants, such as jig plants, becoming more of a boutique design. Selection of these processes no longer offers the significant capital saving that once applied. Additionally, as new coal mines are being developed in Australia, there is a trend towards more difficult separations being required.

Large coal dense medium baths or drums being designed into new plants. Australia has been very quick to adopt large diameter dense medium cyclone technology and there are now many installations of 1300 mm to 1450 mm units. Note for these larger units, there is evidence of poorer separation of the finer fractions, approximately -4 mm.2

Water-based processing can be applied to fine coal, as well as coarse coal (in separate circuits). Water-based separation technologies for fine coal include water washing cyclones, hindered bed separators and spirals. In the case of water-based processing, best results are obtained when processes are limited to narrow size fraction ranges, to minimise size separation/density separation interaction.

Cyclone classification
Hydrocyclones are used extensively in coal preparation for classifying and thickening duties. Classification is the separation of a stream into separate coarse and fine streams, whereas thickening is the removal of water from a stream before subsequent dewatering. Hydrocyclones are typically used to separate in the size range 0.25 mm down to 0.06 mm and, generally, no alternative technology exists for this duty. The recent trend of installing fewer cyclones of larger diameter (up to 1000 mm) has proven to be less than ideal, with these larger cyclones generally providing relatively poor size separations.

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Figure 1. Typical in-plant size distributions.

Figure 2. Typical washability for Queensland metallurgical coal.
Froth flotation
Because froth flotation is based on the difference in surface chemistry between coal and gangue, it is generally only suitable for treating fine coal up to a top-size of 0.5 mm w/w. Metallurgical performance is poorer on the coarser particles (>0.35 mm). Most new operations now opt for column flotation technology. Froth flotation has traditionally only been considered viable in Australia for metallurgical coal resources, where the premium price of the product helps to justify the additional capital investment required.

General Australian approach to processing
In Australia, raw coal is typically crushed to 50 – 60 mm top-size before full wet processing. Raw coal is crushed in low to medium speed sizers before being fed to the plant. The crushed coal is usually deslimed at between 0.7 and 3 mm on high capacity, multi-slope (banana) screens.

The most widely used process for beneficiating coarse coal is by dense medium cyclone. In recently built plants, these are typically 1150 mm in diameter or larger. However, there are still a number of older plants in operation with dense medium vessels and a few with jigs.

The use of banana screens to achieve a size cut of about 2 mm has lead to the undersize containing appreciable quantities of sand-sized particles (-2+0.3 mm), with this sized material not well benefitted by flotation. Thus, there is a need to treat the fine coal by water-based gravity separators, such as spirals or hindered bed separators. These devices cannot treat ultra-fine coal and, where it is essential that the whole size distribution be recovered, froth flotation must also be employed. Most new or upgraded plants producing metallurgical coal employ a mid circuit with spirals or TBS units treating the -2+0.3 mm fraction and the -0.3 mm processed by flotation. While older plants employ banks of mechanical flotation cells, new installations are more likely to employ column technology, with Jameson Cells and Microcells the most prominent.

Coarse and mid-size coal fractions are invariably dewatered in vibrating or scroll-type basket centrifuges, while the flotation product is dewatered on vacuum filters (mainly horizontal belt and disc) or in screen bowl centrifuges. Tailings are dewatered in high rate gravity thickeners. Normal practice in the past has been to pump thickened tailings to dams. However stricter environmental regulations and a need to minimise water usage in drier areas has meant that many new operations are employing mechanical dewatering devices for tailings, with belt press filters most commonly applied.

The combination of high capacity banana screens and large diameter dense medium cyclones has meant that very cost effective coal preparation plant modules can be provided, treating up to 1000 tph, that have one desliming screen, two drain and rinse screens (product and reject) and a single dense medium cyclone.

Queensland metallurgical coals
These coals are relatively higher in rank, have low to medium volatile matter and have appreciable levels of vitrinite. Thus, the coals tend to be friable, leading to relatively fine size distributions. A typical sizing for such coals is shown in Figure 1, but there is a wide range of sizings observed due to differences in vitrinite reflectance (1.0 – 1.6), non-coal contamination and handling intensity. This means that the level of
-0.5 mm ww can range from 20% to 35%. Figure 2 contains an indicative washability of Queensland metallurgical coals, but these can also vary appreciably. For these coals, it is important to have a good recovery from the fine fractions. The cut point for the dense medium processes are typically 1.45 – 1.60 RD.

A typical metallurgical coal circuit is shown in Figure 3, in which coal is usually wet screened at 0.5 mm ww. Coarse coal is washed in dense medium cyclones and dewatered in a basket centrifuge. Froth flotation is employed to treat the fine coal and the flotation concentrate is dewatered on a vacuum filter. When enhanced water removal is required, a combination of filters and screen bowl centrifuges has been successfully used.

In response to losses of the coarser fractions from traditional flotation circuits (for example >0.35 mm), a mid circuit is often now employed, as shown in Figure 4. Here the feed is deslimed at about 2 mm, with the +2 mm processed in dense medium cyclones. The ~2 mm stream is then classified in cyclones, at about 0.25 mm, with the mid-sized fraction cleaned by spirals or hindered bed separators. The ultra-fine fraction is treated by froth flotation.

There has been a need to utilise poorer quality resources, that do not readily yield prime metallurgical coals. Washability is generally satisfactory, as shown as an example in Figure 5, but vitrinite levels are lower. Of significance is that the metallurgical properties show great variation with size and density, such as the crucible swelling number (CSN) shown in Figure 6. A single stage plant would provide a semi-hard metallurgical coal. However, in order to enhance metallurgical coal quality, lower cut points are required, leading to two-stage dense medium processing being applicable. Additionally, the exclusion of the coarsest fraction (for example +16 mm) from the primary product, maximises the metallurgical properties of this product. This increases the complexity of the plant circuit (Figure 7) and the secondary product is generally higher in ash, destined for the pulverised coal injection (PCI) or thermal market.

**Thermal coals**

Since the late 1970s, the export thermal coal market has grown rapidly. The majority of export thermal coal comes from the Hunter Valley in New South Wales and is exported through Newcastle. However, there is now significant activity directed towards establishing major thermal coal mines in Queensland to the west and south of the Bowen Basin.
In preparing export thermal coals, the objective is to maximise the recovery of calorific value and to minimise total moisture. Coals tend to be from lower-rank bituminous measures, with medium to high volatile matters. The coal tends to be much harder (Figure 1), and so contain less fines, than the Queensland metallurgical coals. However, the coal seams are often associated with swelling clays that result in the ultra-fine fractions (for example, -0.1 mm) having a high ash content. Depending on the level of non-seam material present, ultra-fine levels can increase significantly, leading to tailings capacity being of major importance. Figure 8 shows a typical washability, but this can vary from seam to seam and regionally. Some of these coals can also be washed to lower ash semi-soft metallurgical or PCI coals. The product coal is appreciably lower in value than metallurgical coal (6700 kcal/kg gad benchmark), so different processing strategies are employed.

The flowsheet for a typical Hunter Valley coal is shown in Figure 9. Coal is crushed to -50 mm before desliming at about 2 mm. The +2 mm is treated in dense medium cyclones and the product dewatered in basket centrifuges. The -2 mm stream passes to classifying cyclones and the -0.1 mm is discarded to the thickener due to its high ash content and because its presence in product coal would greatly increase the moisture content. The -2+0.1 mm fraction is upgraded by a water-based gravity process, often spirals.

For larger desliming apertures (such as 3 mm), a split fine coal cleaning circuit is preferred to limit the feed size range in each water-based process. Figure 10 shows a combination of a TBS and spirals for treating the fine coal, which together provide a better metallurgical result than spirals or TBS alone treating the full size range.

**Conclusion**

For the Australian coal industry to remain competitive, it is essential that equipment and processing strategies continue to improve to ensure that coal preparation operations improve efficiencies and reduce costs. Incremental and step improvements come about through various sources including industry funded R&D, plants striving for better operations, design improvements and product developments.

**References**