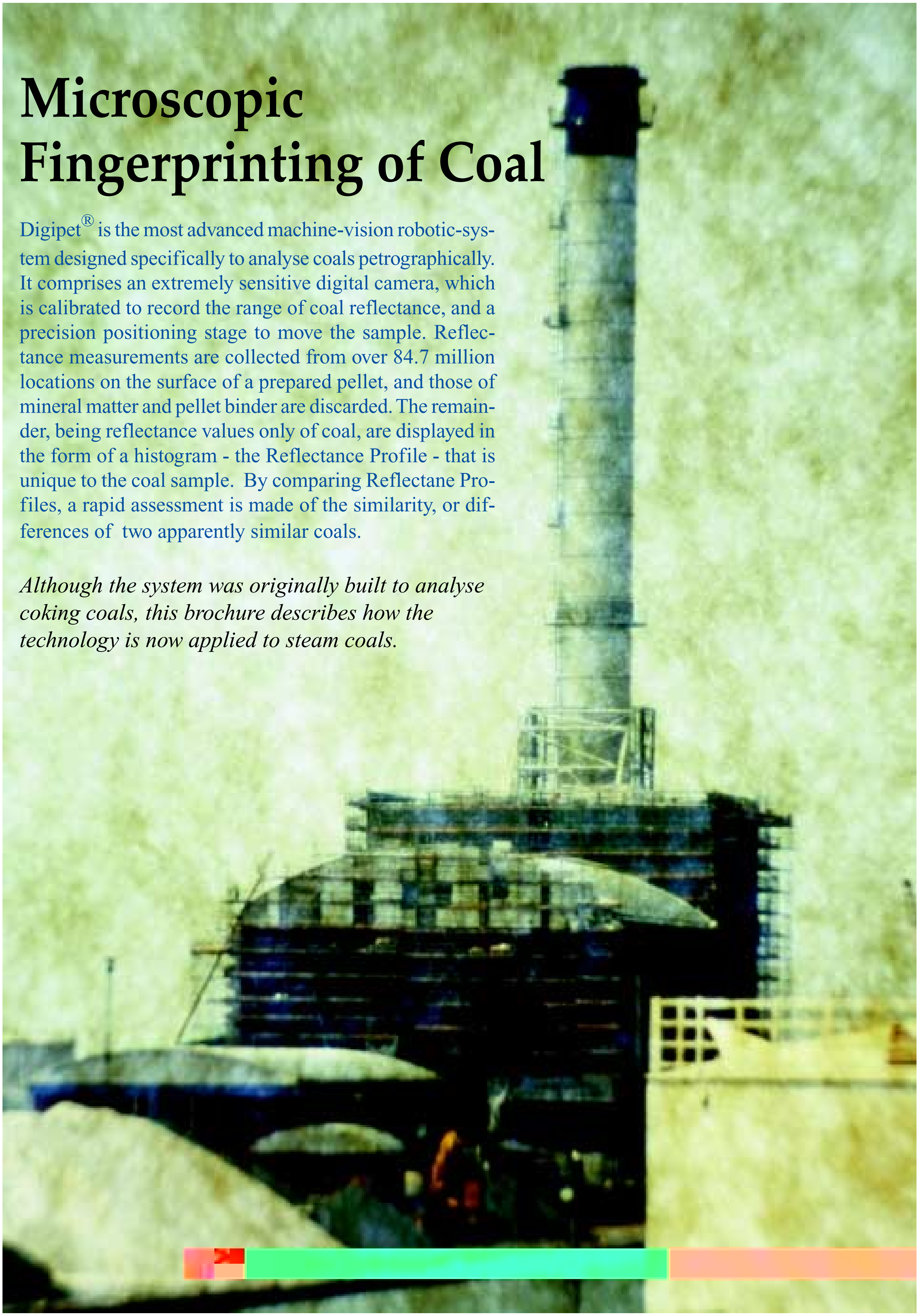
Fingerprinting

Coals & Blends

Pearson Coal Petrography Inc.

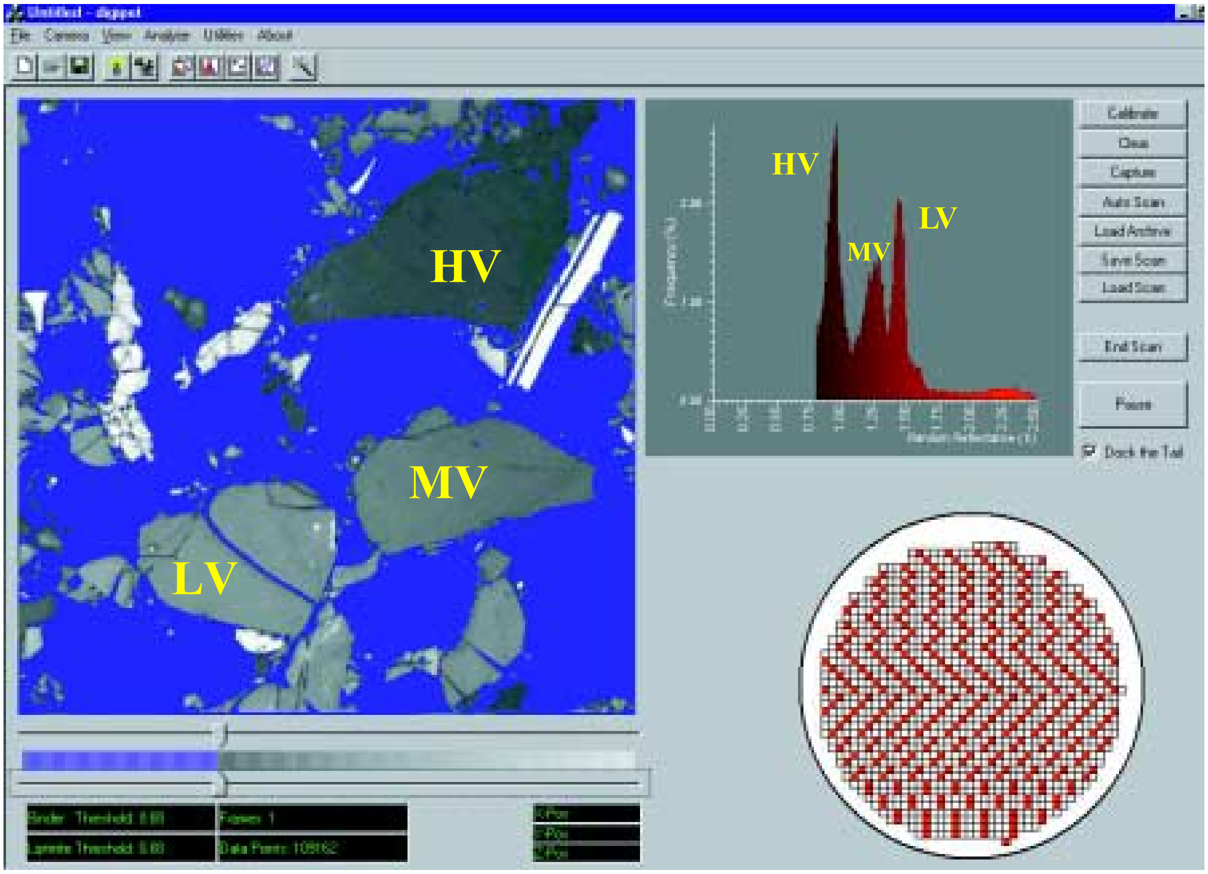
Microscopic Fingerprinting of Coal



Digipet® is the most advanced machine-vision robotic-system designed specifically to analyse coals petrographically. It comprises an extremely sensitive digital camera, which is calibrated to record the range of coal reflectance, and a precision positioning stage to move the sample. Reflectance measurements are collected from over 84.7 million locations on the surface of a prepared pellet, and those of mineral matter and pellet binder are discarded. The remainder, being reflectance values only of coal, are displayed in the form of a histogram - the Reflectance Profile - that is unique to the coal sample. By comparing Reflectane Profiles, a rapid assessment is made of the similarity, or differences of two apparently similar coals.

Although the system was originally built to analyse coking coals, this brochure describes how the technology is now applied to steam coals.

What's a fingerprint?



The large square above is an image captured by the digital camera. The blue is binder, and the gray and white grains are coal. The image contains three different ranks of coal; High-vol (HV), Med-vol (MV), and Low-Vol (LV) vitrinites are labelled. The Reflectance Profile of this image is shown at top right, and contains three distinct peaks - each corresponding to the volume occupied by the different ranks of coal. An image consists of 262,000 pixels, but because of the 58% binder, there are only 110,000 coal reflectance values comprising the reflectance histogram. On a sample of coal, 339 such images are captured in ten minutes. The resulting Reflectance Profile is the most detailed spectrum of the coal's character that can be measured by today's technology, and can be considered a state-of-the-art fingerprint.

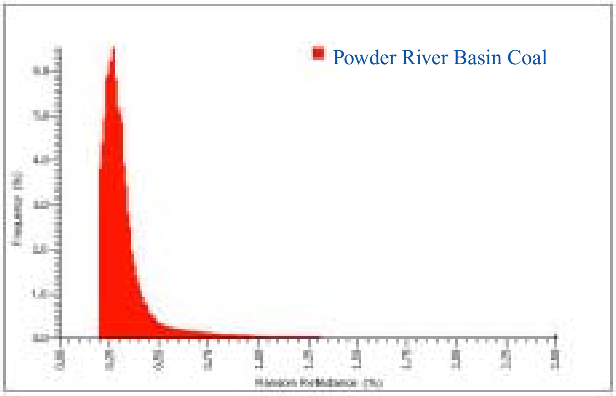
Reflectance Profiling of a single coal will let you do the following.

- Quality Control - confirm a sample is the same as the last example received or shipped, and is uncontaminated by other coals or materials.
- Determine the Calorific Value (daf basis) of the coal.

Fingerprinting of blends quickly enables you to -

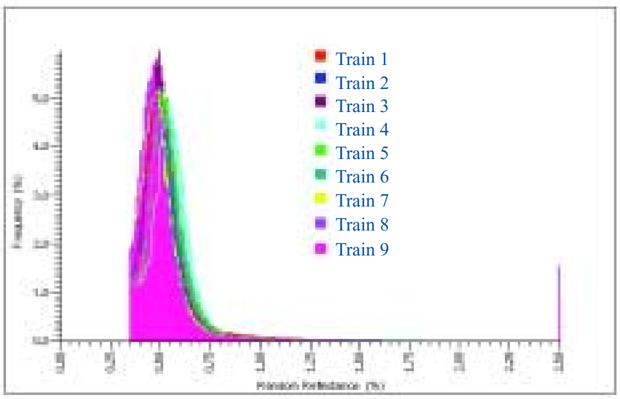
- Determine the blend proportions - whether or not the component coals are mixed in the required recipe.
- Derive the Calorific Value of the blend sample.

The Uniqueness of Fingerprints

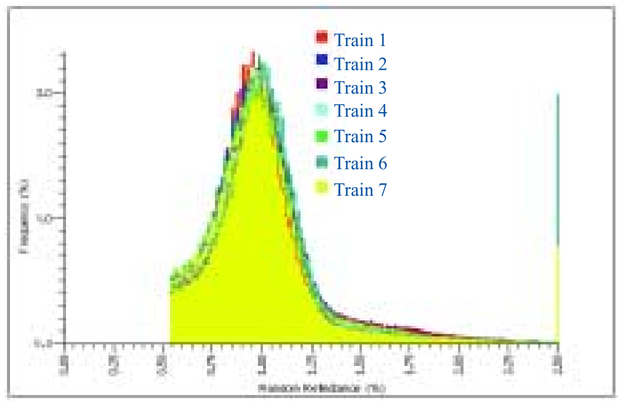


Powder River Basin Random Ro 0.35%, CV 12900 BTU/lb (daf)

Steam coals in the United States are either used locally, or transported by unit train or barge from the three principal coal producing regions of Powder River Basin, Illinois Basin and the Appalachian coalfield, to utilities around the nation. Coals from these geographically distinct areas, although superficially similar, are different in many characteristics, (age, rank, calorific value, type of ash, etc.), including the uniqueness of their Reflectance Profiles. Each coal has a distinctive Reflectance Profile and a corresponding specific energy content.



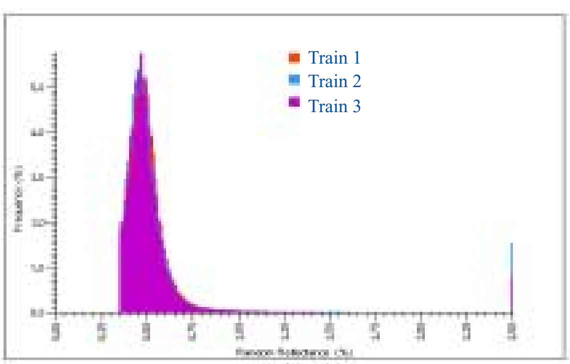
Illinois Basin Random Ro 0.55%, CV 13500 BTU/lb (daf)



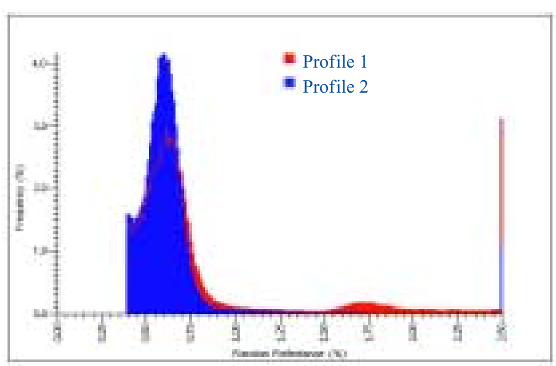
Appalachian HiVol Random Ro 0.82%, CV 15100 BTU/lb (daf)

Monitor Cargo Consistency by Fingerprints

Because reflectance profiles are unique, they can be used to identify in successive cargoes any changes which may be present, whether caused by geological change and substitution (rank and type), or alteration by contamination. Reflectance Profiling is therefore a rapid screening technique to identify consistency or differences.

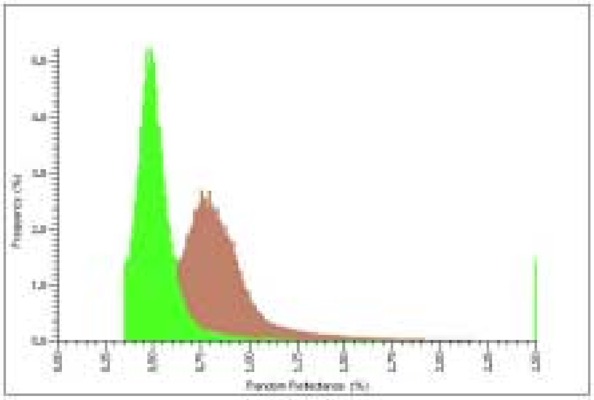


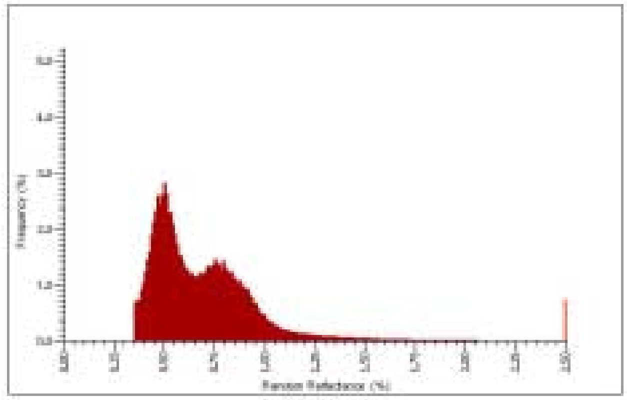
An example of consistency. Three train cargoes. (The Reflectance Profiles are identical and are stacked, one on another).



An example of contamination. The two Reflectance Profiles should be identical, but the red one contains 10% Low Vol Coal (bump at 1.75%).

Designing a Target Blend using Fingerprints

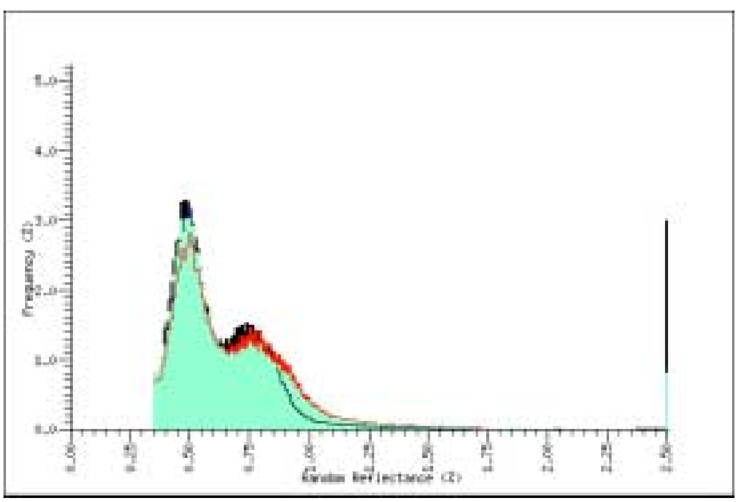




Reflectance Profiles of the individual coals to be used in making a blend are assembled and the computer mixes them together in the proportions of the desired recipe. This preliminary stage is shown above.

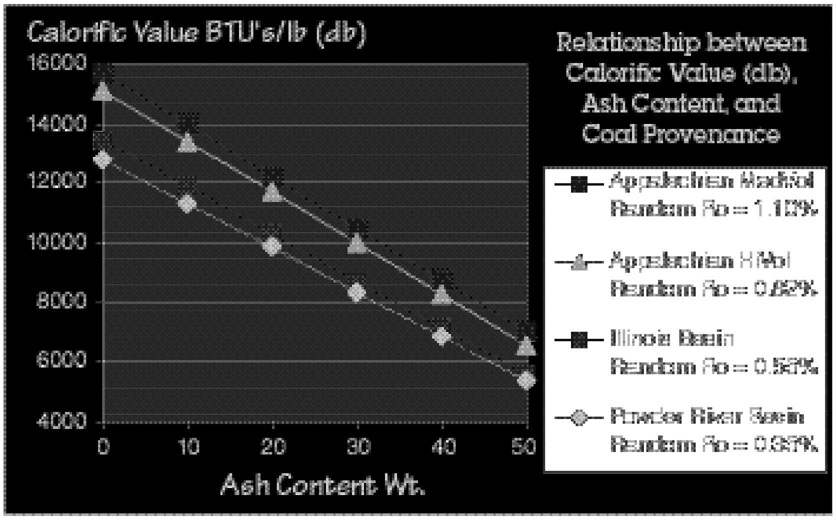
The computer "designed" Reflectance Profile of the target blend is displayed together with a listing of the proportions of the individual component coals, in this case 50:50. The finished product is shown above.

Interpretation of a Blend Sample by a Fingerprint



After the blend sample has been analysed, the Reflectance Profile is displayed (shown in black in the examples above). The computer then mixes the individual component coals to replicate, as close as possible, this Reflectance Profile. This modelled profile is shown in blue. The blue and black profiles are therefore fairly close, and from this modelled best-fit solution, the composition of the blend sample is resolved. The actual and modelled profiles are then compared with the target blend (shown in red). The lower left shows good correspondance between the sample's Reflectance

Calorific Value from Reflectance



Linear regressions of Calorific Value (db) versus raw Ash Content (db) are shown opposite for four different ranks of coal. Between these, many other regression lines can be interpolated. This relationship is the key to predicting the dry, ash-free-basis Calorific Value of a coal directly from a Reflectance Profile, and calculating the net value for specific moisture & ash contents.

Calculation of Calorific Value of a Blend Sample

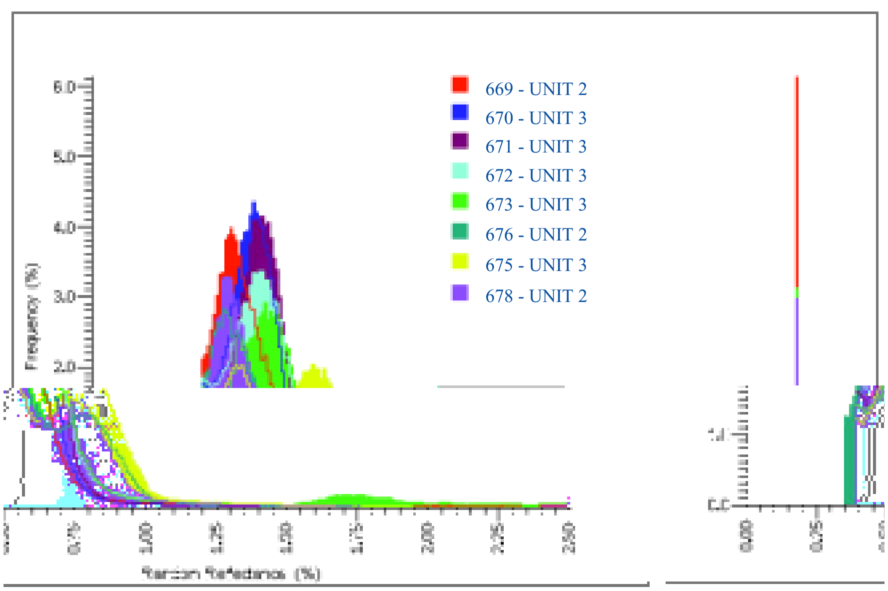
Calculation of Calorific Value of Blend Sample: Unit 2

Coal I.D.	Random Reflectance	Calorific Value (BTU daf)	Ash (As Rec'd)	Tot. Moisture	Calculated (As Rec'd)	Proportion in Blend (%)
Coal A	0.48%	14391	9.93	15.56	10723	50
Coal B	0.85%	15092	7.69	14.09	11805	50

Calculated CV of Blend = 11264 BTU's/lb

A spreadsheet is used to calculate the CV of a blend sample based on the following data:- Random reflectance of the components; CV of components (use either lookup function from reflectance, or the actual value if known), moisture and ash of components; proportions of components in the sample of the blend.

Monitor Power Station Blends



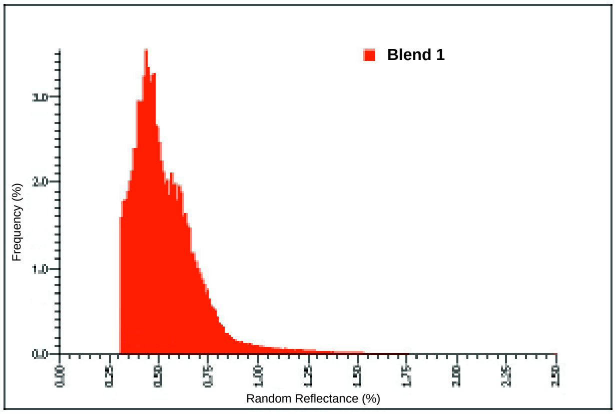
Despite the variation in Reflectance Profiles of the utility blends shown opposite, the net calorific values differ by less than 1600 BTU's/lb. The mauve colored blend (#678) at the front of the graph, for example, is a 60:40 mix of Illinois Basin coal with Appalachian HV, with a net CV of 11500; and the yellow (#675), is 35:65, with a net CV of 12300. However, not all variation is as carefully planned or anticipated as in this case.

Steam Coals in the United States show considerable variation in terms of Calorific Value (BTU's/lb), Random Vitrinite Reflectance, and ASTM rank, but, nevertheless, fall within a distinct envelope. Coals of hvBb and lower rank cover a wide range of calorific value, about 2500 BTU/lb (daf), but only 0.30% in random reflectance. In contrast, coals of hvAb and higher rank, cover only about 1500 BTU/lb (daf), but about 0.80% random reflectance.

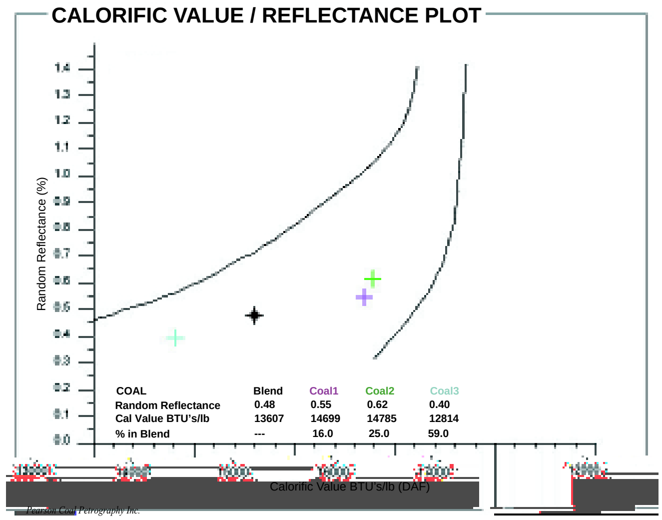
Among coals of hvAb and mvb ASTM rank, the increasing random vitrinite reflectance is accompanied by an increase in Fuel Ratio, that follows a linear relationship, defining the reactivity of steam coals. Among subC and hvBb rank coals, reactivity is much higher than would be expected on the basis of random reflectance. Use of the high-reactivity / lower-reflectance coals results in two blending patterns among steam coals - Low-Rank Blending, and HiVol Blending, shown below.

Low-Rank Blending involves coals with reflectance below 0.60%, and a large range of calorific values, perhaps >2500 BTU/lb (daf).

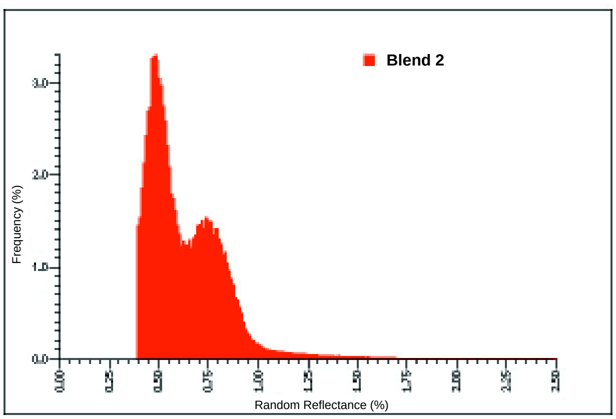
Predicting Calorific Value of Blends



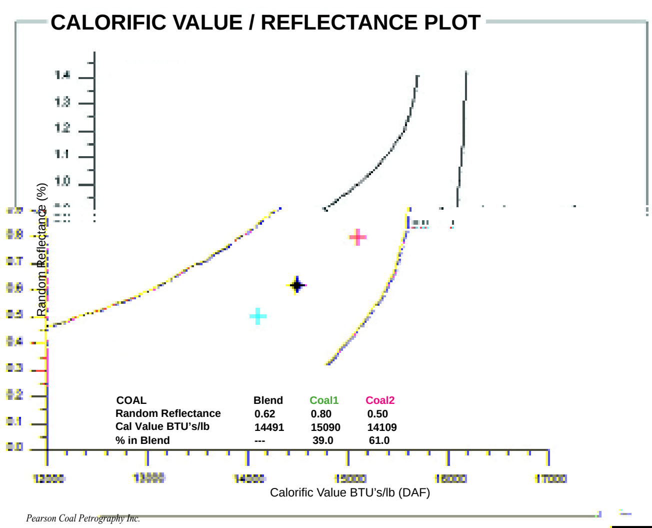
Example of Low-Rank Blending



Three low-rank coals comprise the Fingerprint shown above, and interpretted on the right. Because of the CV spread of fuels used, blend proportions should be monitored in this situation, because the potential is present for wide swings in calorific value of fuel delivered to the boiler.



Example of Hi-Vol Blending



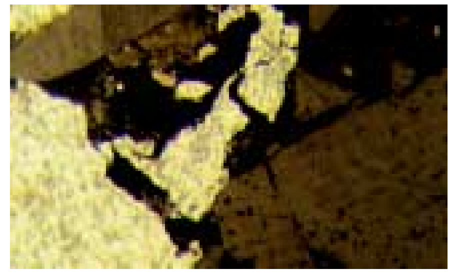
Two coals of hvCb & hvAb rank comprise the Fingerprint shown above, and interpretted on the right. Careful monitoring of the blend in this scenario is less critical, because the small range of calorific values of the component coals means less variation in the blend delivered to the boiler.

Petrography & Combustion

Although Fingerprinting of coals is a powerful tool, so too is standard microscopic observation and petrographic analysis in the identification of contaminants and characterization of carbon forms in fly ash.

Contaminants

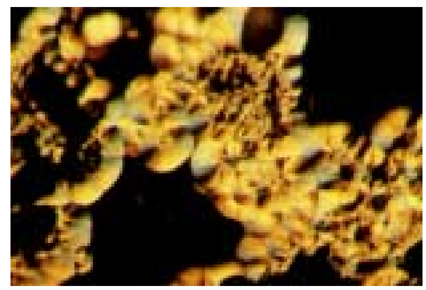
Great care is taken to ensure that coals reach users in contract-specification condition, but occasionally, mishaps do occur, and contamination takes place. We have assembled a library of materials that have been located in coals (wood, brick, limestone, petroleum coke, rubber tire, plastic, coal), some of which are shown here.



Petroleum coke in Sub-bituminous coal

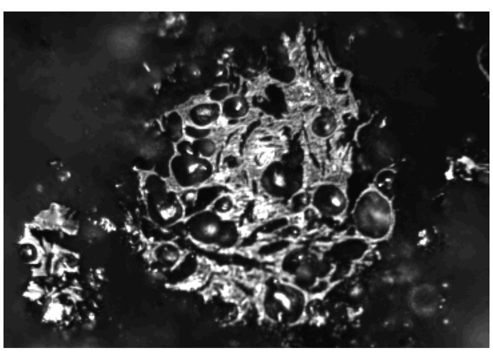
Recycled plastic

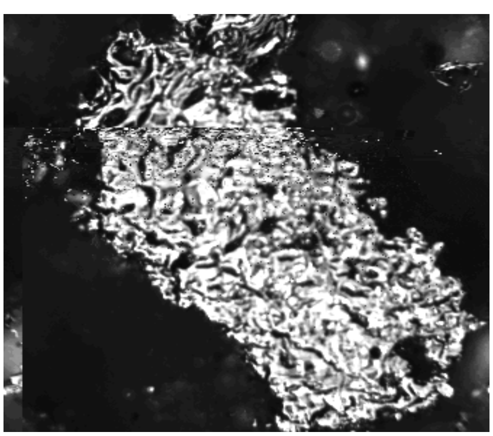
Anthracite in charcoal briquette



Pyrolitic carbon

Carbon forms in Fly Ash





Morphologies of chars in fly ash are a function of the coal's macerals. For example, vitrinite macerals form thin-walled, porous spherical chars, - cenospheres. Semifusinite macerals form less porous, honeycomb structures, - tenui- and crassinetworks. Fusinite maceral may pass through the combustion process unfused, and form inertoids & solid fusinoids.

Analysis of char residues in combustion ash provides information on reactivity and type of coals being burned, or perhaps more importantly, not combusted.

On the left are images of tenuinetwork char from a test burn of a low rank coal, and coarse mesophase petroleum coke, exhibiting poor burnout, both from the same sample.