ANALYSIS OF CHEROKEE GROUP CUTTINGS SAMPLES FOR GAS CONTENT
-- DART CHEROKEE BASIN OPERATING COMPANY
#D1-30 KINCAID TRUST; SW SW sec. 30-T.34S.-R.14E.;
MONTGOMERY COUNTY, KANSAS

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SUMMARY

Five cuttings samples from the Pennsylvanian Cherokee Group were collected from the Dart Cherokee Basin #D1-30 Kincaid Trust well, SW SW sec. 30-T.34S.-R.14E. in Montgomery County, KS. The samples calculate as having the following gas contents:

- Mineral coal at 1213' to 1214' depth (171.4 scf/ton)
- Weir-Pittsburg coal at 1291' to 1292' depth (53.6 scf/ton)
- Dry Wood coal. at 1427' to 1429' depth (45.6 scf/ton)
- Riverton coal at 1510' to 1512' depth (87.0 scf/ton)
- Riverton "rider" coal at 1522' to 1524' depth (125.3 scf/ton)

assuming accompanying dark shales in sample desorb 3 scf/ton

BACKGROUND

The Dart Cherokee Basin #D1-30 Kincaid Trust well, SW SW sec. 30-T.34S.-R.14E. in Montgomery County, KS, was selected for cuttings desorption tests in association with an on-going coalbed gas research project at the Kansas Geological Survey. The samples were gathered March 18, 2004, by K.D. Newell of the Kansas Geological Survey. Samples were obtained during normal drilling of the well, with no cessation of drilling before zones of interest (i.e., coals and dark shales in the Cherokee Group) were penetrated. The well was drilled using an air rotary rig owned by McPherson Drilling.

Lag times for samples to reach the surface (important for assessing lost gas) were determined by using the lag times from a nearby air-drilled well (Dart Cherokee Basin #C4-26 Gritton; sec. 26-T.33S.-R.14E., Montgomery County, KS). The lag times were determined by periodically noting the time it took for cuttings to reach the surface following resumption of drilling after new pipe was added to the drill string.

Five cuttings samples from the Pennsylvanian Cherokee Group were collected:

- Mineral coal at 1213' to 1214' depth (516 grams dry wt.)
- Weir-Pittsburg coal at 1291' to 1292' depth (747 grams dry wt.)
- Dry Wood coal. at 1427' to 1429' depth (581 grams dry wt.)
- Riverton coal at 1510' to 1512' depth (970 grams dry wt.)
- Riverton "rider" coal at 1522' to 1524' depth (227 grams dry wt.)

The cuttings were caught in kitchen strainers as they exited the air-stream pipe emptying to the mud pit. The samples were then washed in water while in the kitchen strainers to rid them of as much drilling mud as possible before the cuttings were placed in desorption canisters. In case of small sample size (i.e., for the Riverton "rider" coal sample -- less than 600 grams dry wt.), a concrete plug was placed in the desorption canister to decrease the volume of free space within the canister. The volume of this plug was 77 cubic inches (1262 cm³). Water with zephym chloride biocide was added to the sample before sealing the canister. A headspace of approximately 5 cm was left in each canister.
Temperature baths for the desorption canisters were on site, with temperature kept at approximately 80 °F. The canistered samples at the end of the day were transported to the laboratory at the Kansas Geological Survey in Lawrence, KS, and desorption measurements were continued at approximately the same temperature. Desorption measurements were periodically made until the canisters produced negligible gas with daily testing for at least two successive days.

DESORPTION MEASUREMENTS

The equipment and method for measuring desorption gas is that prescribed by McLennan and others (1995). The volumetric displacement apparatus is a set of connected dispensing burettes, one of which measures the gas evolved from the desorption canister. The other burette compensates for the compression that occurs when the desorbed gas displaces the water in the measuring burette. This compensation is performed by adjusting the cylinders so that their water levels are identical, then figuring the amount of gas that evolved by reading the difference in water level using the volumetric scale on the side of the burette.

The desorption canisters were made in-house at the Kansas Geological Survey and bought commercially. The Maggy canisters were made in-house. On average, these canisters are approximately 15 inches long (38.1 cm), 3 inches (7.6 cm) in diameter, and enclose a volume of approximately 106 cubic inches (1740 cm³). Commercial canisters were also used. The Mer I canister was obtained from PEL-I-CANS (by J.R. Levine) in Richardson, TX. This canister is 11.2 inches high (28.5 cm), 3.8 inches (9.7 cm) in diameter, and encloses a volume of approximately 127 cubic inches (2082 cm³). Commercial canisters from SSD, Inc. in Grand Junction, CO, were used for the remaining samples. These canisters are 12.5 inches high (32 cm), 3 1/2 inches (9 cm) in diameter, and enclose a volume of approximately 150 cubic inches (2450 cm³).

The desorbed gas that collected in the desorption canisters was periodically released into the volumetric displacement apparatus and measured as a function of time, temperature, and atmospheric pressure.

The time and atmospheric pressure were measured in the field using a portable weather station (model BA928) marketed by Oregon Scientific (Tualatin, OR). The atmospheric pressure was displayed in millibars on this instrument, however, this measurement was not the actual barometric pressure, but rather an altitude-compensated barometric pressure automatically converted to a sea-level-equivalent pressure. In order to translate this measurement to actual atmospheric pressure, a regression correlation was determined over several weeks by comparing readings from the Oregon Scientific instrument to that from a pressure transducer in the Petrophysics Laboratory in the Kansas Geological Survey in Lawrence, KS (Figure 1). The regression equation shown graphically in Figure 1 was entered into a spreadsheet and was used to automatically convert the millibar measurement to barometric pressure in pounds per square inch (psi).
A spreadsheet program written by K.D. Newell (Kansas Geological Survey) was used to convert all gas volumes at standard temperature and pressure. Conversion of gas volumes to standard temperature and pressure was by application of the perfect-gas equation, obtainable from basic college chemistry texts:

\[ n = \frac{PV}{RT} \]

where \( n \) is moles of gas, \( T \) is degrees Kelvin (i.e., absolute temperature), \( V \) is in liters, and \( R \) is the universal gas constant, which has a numerical value depending on the units in which it is measured (for example, in the metric system \( R = 0.0820 \) liter atmosphere per degree mole). The number of moles of gas (i.e., the value \( n \)) is constant in a volumetric conversion, therefore the conversion equation, derived from the ideal gas equation, is:

\[ \frac{P_{\text{stp}} V_{\text{stp}}}{(RT_{\text{stp}})} = \frac{P_{\text{rig}} V_{\text{rig}}}{(RT_{\text{rig}})} \]

Customarily, standard temperature and pressure for gas volumetric measurements in the oil industry are 60 °F and 14.7 psi (see Dake, 1978, p. 13), therefore \( P_{\text{stp}} \), \( V_{\text{stp}} \), and \( T_{\text{stp}} \), respectively, are pressure, volume, and temperature at standard temperature and pressure, where standard temperature is degrees Rankine (°R = 460 + °F). \( P_{\text{rig}} \), \( V_{\text{rig}} \), and \( T_{\text{rig}} \), respectively, are ambient pressure, volume and temperature measurements taken at the rig site or in the desorption laboratory.

The universal gas constant \( R \) drops out as this equation is simplified and the determination of \( V_{\text{stp}} \) becomes:

\[ V_{\text{stp}} = \left( \frac{T_{\text{stp}}}{T_{\text{rig}}} \right) \left( \frac{P_{\text{rig}}}{P_{\text{stp}}} \right) V_{\text{rig}} \]

The conversion calculations in the spreadsheet were carried out in the English metric system, as this is the customary measure system used in American coal and oil industry. \( V \) is therefore converted to cubic feet; \( P \) is psia; \( T \) is °R.

The desorbed gas was summed over the time period for which the coal samples evolved all of their gas. In the case of well cuttings from Dart Cherokee Basin #D1-30 Kincaid Trust well, the maximum time of desorption was 11 days.

Lost gas (i.e., the gas lost from the sample from the time it was drilled, brought to the surface, to the time it was canistered) was determined using the direct method (Kissel and others, 1975; also see McLennan and others, 1995, p. 6.1-6.14) in which the cumulative gas evolved is plotted against the square root of elapsed time. Time zero is assumed to be the moment that the rock is cut and its cuttings circulated off bottom. Characteristically, the cumulative gas evolved from the sample, when plotted against the square root of time, is linear for a short time period after the sample reaches ambient surface pressure conditions, therefore lost gas is determined by a line projected back to time zero. The period of linearity generally is about an hour for cuttings samples.
LITHOLOGIC ANALYSIS

Upon removal from the canisters, the cuttings were washed of drilling mud, and dried in air for several days. After drying, the cuttings were weighed and then dry sieved into 5 size fractions: >0.0930", >0.0661", >0.0460", >0.0331", and <0.0331". For large sample sizes, the cuttings were ran through a sample splitter and a lesser portion (approximately 75 grams) were sieved and weighed, and the derived size-fraction ratios were applied to the entire sample.

The size fractions were then inspected and sorted by hand under a dissecting microscope. Three major lithologic categories were differentiated: coal, dark shales (generally Munsell rock colors N3 (dark gray), N2 (grayish black), and N1 (black) on dry surface), and lighter-colored lithologies and/or dark and light-colored carbonates. The lighter-colored lithologies are considered to be incapable of generating significant amounts of gas. After sorting, and for every size class, each of these three lithologic categories was weighed and the proportion of coal, dark shale, and light-colored lithologies were determined for the entire cuttings sample based on the weight percentages.

DATA PRESENTATION

Data and analyses accompanying this report are presented in the following order: 1) lag time to surface for the well cuttings, 2) data tables for the desorption analyses, 3) lost-gas graphs, 4) “lithologic component sensitivity analyses” showing the interdependence of gas evolved from dark shale versus coal in each sample, 5) a summary component analysis for all samples showing relative reliability of the data from all the samples, and 6) a desorption graph for all the samples.

Graph of Lag-time to Surface for Well Cuttings (Figure 2)
Lag time of cuttings to surface varied, but there is a general trend of longer lag times for greater depth. The lag times accepted for cuttings were taken to be a visual average of the trend (defined by the scatter of data points on this graph) at the depth at which the samples were taken. The well used for this graph was the nearby Dart Cherokee basin #c4-26 Gritton, drilled in sec. 26-T.33S.-R.14E.

Data Tables of the Desorption Analyses (Table 1)
These are the basic data used for lost-gas analysis and determination of total gas desorbed from the cuttings samples. Basic temperature, volume, and barometric measurements are listed at left. Farther to the right, these are converted to standard temperature, pressure and volumes. The volumes are cumulatively summed, and converted to scf/ton based on the total weight of coal and dark shale in the sample. At the right of the table, the time of the measurements are listed and converted to hours (and square root of hours) since the sample was drilled.
Lost-Gas Graphs (Figures 3-7)
Gas lost prior to the canistering of the sample was estimated by extrapolation of the first few data points after the sample was canistered. The linear characteristic of the initial desorption measurements is usually lost within the first hour after the cuttings leave the bottom of the hole, thus data are presented in the lost-gas graphs for only up to one hour after cuttings are off bottom. Lost-gas volumes derived from this analysis are incorporated in the data tables described above.

"Lithologic Component Sensitivity Analyses" (Figures 8-12)
The rapidity of penetration of an air-drilled well makes collection of pure lithologies from relatively thin-bedded strata rather difficult. Mixed lithologies are more the norm rather than the exception. Some of this mixing is due to cavings from strata farther up hole. The mixing may also be due to collection of two or more successively drilled lithologies in the kitchen sieve at the exit line, or differential lifting of relatively less-dense coal compared to other lithologies, all of which are more dense than coal.

The total gas evolved from the sample is due to gas being desorbed from both the coal and dark shale. Both lithologies are capable of generating gas, albeit the coal will be richer in gas than the dark-colored shale. Even though dark-colored shale is less rich in sorbed gas than coal, if a sample has a large proportion of dark, organic-rich shale and only a minor amount of coal, the total volume of gas evolved from the dark-shale component may be considerable. The lighter-colored lithologies are considered to be incapable of generating significant amounts of gas.

The total amount of gas evolved from a cuttings sample can be expressed by the following equation:

\[ \text{Total gas (cm}^3\text{)} = [\text{weight}_\text{coal (grams)} \times \text{gas content}_\text{coal (cm}^3/\text{gram})] + [\text{weight}_\text{dark shale (grams)} \times \text{gas content}_\text{dark shale (cm}^3/\text{gram})] \]

A unique solution for \( \text{gas content}_\text{coal} \) in this equation is not possible because \( \text{gas content}_\text{dark shale} \) is not known exactly. An answer can only be expressed as a linear solution to the above equation. The richer in gas the dark shales are, the poorer in gas the admixed coal has to be, and vice versa. If there is little dark shale in a sample, a relatively well constrained answer for \( \text{gas content}_\text{coal} \) can be obtained. Conversely, if considerable dark shale is in a sample, the gas content of a coal will be hard to precisely determine.

The lithologic-component-sensitivity-analysis diagram therefore expresses the bivariant nature inherent in the determination of gas content in mixed cuttings. The gas content of dark shales in Kansas can vary greatly. Proprietary desorption analyses of dark shales in cores from southeastern Kansas have registered as much as 50 scf/ton, but can be as low as 2-4 scf/ton.

A value of 3 scf/ton for average dark shale is based on the assay of the gas content of cores of dark shales in nearby wells. However, high-gamma-ray shales (such as the
Excello Shale), also colloquially known as "hot shales", typically have more organic matter and associated gas content than dark shales with no excessive gamma-ray level. Determination of gas content for a coal associated with a "hot" shale therefore carries more uncertainty than if the coal were associated with a shale without a high gamma-ray value. For example, the Mulky/Excello sample is a coal associated with a "hot shale".

In general, shale gas content does not have to be very much greater that 10 scf/ton before the associated coal starts to have a gas content less than that of the dark shale. In all the lithologic-component-sensitivity-analysis diagrams, a “break-even” point is therefore noted where the gas content of the coal is equal to that of the dark shale. This “break-even” point corresponds to the minimum gas content assignable to the coal and maximum gas content assignable to the dark shale. It can also be thought of the scf/ton gas content of the cuttings sample minus the weight of any of the lighter-colored lithologies, which are assumed to have no inherent gas content. Conversely, to assume that all the gas evolved from a cuttings sample is derived solely from the coal would result in an erroneously high gas content for the coal.

**Summary Component Analysis for all Samples (Figure 13)**

This diagram is a summary of the individual “lithologic component sensitivity analyses” for each sample, all set at a common scale. The steeper the angle of the line for a sample, the more uncertainty is attached to the results (i.e., $gas_{coal}$) for that sample. If the coal content is miniscule (i.e., $< \approx 5\%$), the results are a better reflection of the $gas_{dark\ shale}$.

**Desorption Graph (Figure 14)**

This is a desorption graph (gas content per weight vs. square root of time) for all the samples. The rate at which gas is evolved from the samples is thus comparable at a common scale. The final value represents the standard cubic feet of gas per ton (scf/ton) calculated for the sample, using the combined weight of the coal and dark shale in the sample.

**ASHING and DENSITY EXPERIMENTS**

Simple ashing of the samples was carried out in a muffle furnace at the Kansas Geological Survey. The samples were first weighed and then subjected to 110 °C until their weight stabilized. This first firing approximates moisture content. A second firing at 750 °C for three to four days essentially ashed the sample. Two crucibles of sample were utilized for both the 110 °C and 750 °C firings. Each crucible was filled with approximately 1.5 grams of pulverized coal (i.e., $< 0.0460''$ sieve size). Results were accepted if the difference in weight loss for each sample was less than 2%.

<table>
<thead>
<tr>
<th>unit</th>
<th>depth</th>
<th>moisture</th>
<th>ash</th>
<th>moisture-free ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral</td>
<td>1213'</td>
<td>1.24%</td>
<td>19.33%</td>
<td>19.46%</td>
</tr>
<tr>
<td>Weir-Pittsburg</td>
<td>1291'</td>
<td>1.17%</td>
<td>16.04%</td>
<td>16.23%</td>
</tr>
<tr>
<td>Dry Wood</td>
<td>1427'</td>
<td>0.78%</td>
<td>25.59%</td>
<td>25.74%</td>
</tr>
</tbody>
</table>
Using the equation from McLennan and others (1995):

\[ G_c = G_{pc} (1-a_d) \]

where:
- \( G_c \) = gas content, scf/ton
- \( G_{pc} \) = "pure coal", gas content, scf/ton
- \( a_d \) = dry ash content, weight fraction

the gas content of the samples converts to:

<table>
<thead>
<tr>
<th>unit</th>
<th>depth</th>
<th>moisture-free ash</th>
<th>( G_c )</th>
<th>( G_{pc} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral</td>
<td>1213'</td>
<td>19.46%</td>
<td>171.4 scf/ton</td>
<td>213.1 scf/ton</td>
</tr>
<tr>
<td>Weir-Pittsburg</td>
<td>1291'</td>
<td>16.23%</td>
<td>53.6 scf/ton</td>
<td>64.0 scf/ton</td>
</tr>
<tr>
<td>Dry Wood</td>
<td>1427'</td>
<td>25.74%</td>
<td>45.6 scf/ton</td>
<td>61.4 scf/ton</td>
</tr>
<tr>
<td>Riverton</td>
<td>1510'</td>
<td>37.55%</td>
<td>87.0 scf/ton</td>
<td>139.4 scf/ton</td>
</tr>
<tr>
<td>Riverton &quot;rider&quot;</td>
<td>1522'</td>
<td>22.21%</td>
<td>125.3 scf/ton</td>
<td>161.3 scf/ton</td>
</tr>
</tbody>
</table>

Coal samples, 4 to 5 grams in weight, were also weighed for determination of their density. The weighed samples were then placed in water in a 10-cc graduated cylinder to determine the volume of the sample. The following density measurements were then calculated:

<table>
<thead>
<tr>
<th>unit</th>
<th>depth</th>
<th>density and uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral</td>
<td>1213'</td>
<td>1.40 g/cc ± 0.07</td>
</tr>
<tr>
<td>Weir-Pittsburg</td>
<td>1291'</td>
<td>1.41 g/cc ± 0.07</td>
</tr>
<tr>
<td>Dry Wood</td>
<td>1427'</td>
<td>1.48 g/cc ± 0.07</td>
</tr>
<tr>
<td>Riverton</td>
<td>1510'</td>
<td>1.79 g/cc ± 0.07</td>
</tr>
<tr>
<td>Riverton &quot;rider&quot;</td>
<td>1522'</td>
<td>1.42 g/cc ± 0.07</td>
</tr>
</tbody>
</table>

RESULTS and DISCUSSION

According to the summary diagram for the sensitivity analyses (Figure 13), the best constrained results (in which the resultant coal gas content varies the least with shale gas content) is for the Riverton "rider" coal. The least constrained results are for the Weir-Pittsburg coal.

An estimate for gas content for the coal in these samples can be made, assuming the admixed dark shale in the samples desorb 3 scf/ton. Shale cuttings accompanying the Mineral coal were fossiliferous and very dark. This, and the elevated gamma-ray response of this shale on wireline logs, suggests that this shale may have a gas content
greater than 3 scf/ton. Shale cuttings accompanying the other samples were hues of lighter gray, hence the 3 scf/ton assumption for these shales is likely appropriate.

REFERENCES

FIGURES and TABLES

FIGURE 1. Correlation of field barometer to Petrophysics Lab pressure transducer.
FIGURE 2. Lag-time to surface for well cuttings.
TABLE 1. Desorption measurements for samples.
FIGURE 3. Lost-gas graph for Mineral coal at 1213' to 1214' depth.
FIGURE 4. Lost-gas graph for Weir-Pittsburg coal at 1291' to 1292' depth.
FIGURE 5. Lost-gas graph for Dry Wood coal at 1427' to 1429' depth.
FIGURE 6. Lost-gas graph for Riverton coal at 1510' to 1512' depth.
FIGURE 7. Lost-gas graph for Riverton "rider" coal at 1522' to 1524' depth.
FIGURE 8. Sensitivity analysis for Mineral coal at 1213' to 1214' depth.
FIGURE 9. Sensitivity analysis for Weir-Pittsburg coal at 1291' to 1292' depth.
FIGURE 10. Sensitivity analysis for Dry Wood coal at 1427' to 1429' depth.
FIGURE 11. Sensitivity analysis for Riverton coal at 1510' to 1512' depth.
FIGURE 12. Sensitivity analysis for Riverton "rider" coal at 1522' to 1524' depth.
FIGURE 13. Lithologic component sensitivity analyses for all samples.
FIGURE 14. Desorption graph for all samples.
Correlation of Field Barometer to KGS Petrophysics Lab Barometer

FIGURE 1.
Lag-time to surface for well cuttings; Dart Cherokee Basin #C4-26 Gritton well
(SW SW SW sec. 26-T.33S.-R.14E., Montgomery County, KS)

(used for the lag-time estimation for the Dart Cherokee Basin #D1-30 Kincaid Trust well;
SW SW sec. 30-T.34S.-R.14E., Montgomery County, KS)

FIGURE 2.
<table>
<thead>
<tr>
<th>Sample</th>
<th>Material</th>
<th>Time of Desorption</th>
<th>Time of Sampling</th>
<th>Weight</th>
<th>Volume</th>
<th>Moisture</th>
<th>Ash</th>
<th>Ultimate Analysis</th>
<th>Heating Value</th>
<th>Ash Fusion Temperature</th>
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### SAMPLE: 1427 to 1429 (Dry Wood coal) cuttings in canister D

<table>
<thead>
<tr>
<th>Time</th>
<th>Est. lost gas (cc)</th>
<th>TIME:OF</th>
<th>TIME SINCE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>of bottom</td>
<td>at surface</td>
<td>in canister</td>
</tr>
<tr>
<td>3/26/04</td>
<td>14:32</td>
<td>198:26:00</td>
<td>198:20:45</td>
</tr>
<tr>
<td></td>
<td>14:26</td>
<td>24:16:00</td>
<td>24:10:45</td>
</tr>
<tr>
<td></td>
<td>14:26</td>
<td>3:24:00</td>
<td>3:18:45</td>
</tr>
<tr>
<td>3/28/04</td>
<td>12:21</td>
<td>24:45:00</td>
<td>24:39:45</td>
</tr>
<tr>
<td>3/20/04</td>
<td>13:30</td>
<td>21:45:00</td>
<td>21:39:45</td>
</tr>
<tr>
<td>3/27/04</td>
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<tr>
<td>3/28/04</td>
<td>14:45</td>
<td>39:45:00</td>
<td>39:39:45</td>
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</tbody>
</table>

**CCM SAMPLE: 1427' to 1429' (Dry Wood coal) cuttings in canister D**

<table>
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<tr>
<th>Time</th>
<th>elapsed time (off bottom to canistering)</th>
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<tbody>
<tr>
<td>3/18/04</td>
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<td>27:00:00</td>
</tr>
<tr>
<td>3/28/04</td>
<td>27:30:00</td>
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</tbody>
</table>

### RIGLAB MEASUREMENTS: CONVERSION OF RIGLAB MEASUREMENTS TO STP (100 psi, 70° F, 14.7 psia)

<table>
<thead>
<tr>
<th>Time</th>
<th>measured T (°F)</th>
<th>QG (°F)</th>
<th>QC (°STP)</th>
<th>TIME:OF</th>
<th>TIME SINCE</th>
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</thead>
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<td>3/18/04</td>
<td>9:05</td>
<td>1.39</td>
<td>4.9039E-05</td>
<td>0:00:00</td>
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<td>3/18/04</td>
<td>9:08</td>
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<tr>
<td>3/18/04</td>
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<td>0:00:00</td>
<td>0:00:00</td>
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<tr>
<td>3/18/04</td>
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<td>0:00:00</td>
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</table>

**SAMPLE: 1510 to 1512** (Fluvion coal) cuttings in canister K

<table>
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<th>Time</th>
<th>measured T (°F)</th>
<th>QG (°F)</th>
<th>QC (°STP)</th>
<th>TIME:OF</th>
<th>TIME SINCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/19/04</td>
<td>13:06</td>
<td>15.94</td>
<td>10.94927699</td>
<td>0:00:00</td>
<td>0:00:00</td>
</tr>
<tr>
<td>3/20/04</td>
<td>13:06</td>
<td>15.94</td>
<td>10.94927699</td>
<td>0:00:00</td>
<td>0:00:00</td>
</tr>
<tr>
<td>3/25/04</td>
<td>11:39</td>
<td>8.68</td>
<td>9.07</td>
<td>0:00:00</td>
<td>0:00:00</td>
</tr>
<tr>
<td>3/28/04</td>
<td>12:23</td>
<td>9.17</td>
<td>10.59</td>
<td>0:00:00</td>
<td>0:00:00</td>
</tr>
</tbody>
</table>

**DESORPTION TERMINATED 30/02/04 DUE TO NO MORE GAS BEING EVOLVED; sample air dried for 14 days**

### RIGLAB MEASUREMENTS: CONVERSION OF RIGLAB MEASUREMENTS TO STP (100 psi, 70° F, 14.7 psia)

<table>
<thead>
<tr>
<th>Time</th>
<th>measured T (°F)</th>
<th>QG (°F)</th>
<th>QC (°STP)</th>
<th>TIME:OF</th>
<th>TIME SINCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/20/04</td>
<td>13:06</td>
<td>15.94</td>
<td>10.94927699</td>
<td>0:00:00</td>
<td>0:00:00</td>
</tr>
<tr>
<td>3/25/04</td>
<td>11:39</td>
<td>8.68</td>
<td>9.07</td>
<td>0:00:00</td>
<td>0:00:00</td>
</tr>
<tr>
<td>3/28/04</td>
<td>12:23</td>
<td>9.17</td>
<td>10.59</td>
<td>0:00:00</td>
<td>0:00:00</td>
</tr>
<tr>
<td>TIME OF MEASURE</td>
<td>dry sample weight: 0.3748 170.01</td>
<td>lbs.</td>
<td>grams</td>
<td>est. lost gas (cc)</td>
<td>TIME OF:</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------------------------------</td>
<td>------</td>
<td>--------</td>
<td>-------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>elapsed time (off bottom to canistering)</td>
<td>3/18/04 9:51</td>
<td>3/18/04 9:54</td>
<td>3/18/04 10:00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RIGLAB MEASUREMENTS</td>
<td>CONVERSION OF RIGLAB MEASUREMENTS TO STP (0°F, 14.7 psi)</td>
<td>CUMULATIVE VOLUMES</td>
<td>SCOFFTON</td>
<td>SCOFFTON</td>
<td>TIME OF MEASURE</td>
</tr>
<tr>
<td>measured cc</td>
<td>measured T (°F)</td>
<td>measured P (absolute)</td>
<td>cubic ft (STP)</td>
<td>cc (STP)</td>
<td>without lost gas</td>
</tr>
<tr>
<td>2</td>
<td>77</td>
<td>1090</td>
<td>373</td>
<td>14.146</td>
<td>6.582E-05</td>
</tr>
<tr>
<td>3</td>
<td>76</td>
<td>1090</td>
<td>0.0001</td>
<td>538</td>
<td>14.148</td>
</tr>
<tr>
<td>4</td>
<td>76</td>
<td>1090</td>
<td>0.0001</td>
<td>536</td>
<td>14.146</td>
</tr>
<tr>
<td>4</td>
<td>77</td>
<td>1090</td>
<td>0.0001</td>
<td>537</td>
<td>14.148</td>
</tr>
<tr>
<td>3</td>
<td>77</td>
<td>1090</td>
<td>0.0001</td>
<td>537</td>
<td>14.148</td>
</tr>
<tr>
<td>3</td>
<td>77</td>
<td>1090</td>
<td>0.0001</td>
<td>537</td>
<td>14.148</td>
</tr>
<tr>
<td>2</td>
<td>78</td>
<td>1090</td>
<td>0.0002</td>
<td>538</td>
<td>14.148</td>
</tr>
<tr>
<td>15</td>
<td>80</td>
<td>1097</td>
<td>0.0006</td>
<td>540</td>
<td>14.109</td>
</tr>
<tr>
<td>22</td>
<td>79</td>
<td>1097</td>
<td>0.0006</td>
<td>539</td>
<td>14.109</td>
</tr>
<tr>
<td>16</td>
<td>80</td>
<td>1094</td>
<td>0.0004</td>
<td>540</td>
<td>14.200</td>
</tr>
<tr>
<td>2</td>
<td>79</td>
<td>1102</td>
<td>0.0006</td>
<td>539</td>
<td>14.303</td>
</tr>
<tr>
<td>5</td>
<td>81</td>
<td>1097</td>
<td>0.0002</td>
<td>541</td>
<td>14.239</td>
</tr>
<tr>
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<td>81</td>
<td>1081</td>
<td>0.0001</td>
<td>541</td>
<td>14.031</td>
</tr>
<tr>
<td>9</td>
<td>82</td>
<td>1084</td>
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<td>542</td>
<td>14.070</td>
</tr>
<tr>
<td>4</td>
<td>81</td>
<td>1076</td>
<td>0.0001</td>
<td>541</td>
<td>13.986</td>
</tr>
<tr>
<td>-5</td>
<td>80</td>
<td>1085</td>
<td>0.0001</td>
<td>540</td>
<td>14.070</td>
</tr>
</tbody>
</table>

DESORPTION TERMINATED 3/30/2004 DUE TO NO MORE GAS BEING EVOLVED; sample air dried for 14 days.
1213' to 1214' (Mineral coal) cuttings in canister Maggy 4
Dart Cherokee Basin Kincaid Trust #D1-30; sec. 30-T.34S.-R.14E., Montgomery County, KS

 elapsed time (off-bottom to canister) = 0.454
  = SQRT(0.206 hrs.)  
  = 12.4 min.

33cc estimated lost gas

square root of hours since cuttings were off bottom

FIGURE 3.
1291' to 1292' (Weir-Pittsburg coal) cuttings in canister Maggy 3
Dart Cherokee Basin Kincaid Trust #D1-30; sec. 30-T.34S.-R.14E., Montgomery County, KS

elapsed time (off-bottom to canister)
= 0.296
= SQRT(0.088 hrs.)
= 5.3 min.

7cc estimated lost gas

square root of hours since cuttings were off bottom

FIGURE 4.
1427' to 1429' (Dry Wood coal) cuttings in canister D
Dart Cherokee Basin Kincaid Trust #D1-30; sec. 30-T.34S.-R.14E., Montgomery County, KS

elapsed time (off-bottom to canister) = 0.410
= SQRT(0.168 hrs.)
= 10.1 min.

12cc estimated lost gas

FIGURE 5.
1510' to 1512' (Riverton coal) cuttings in canister K
Dart Cherokee Basin Kincaid Trust #D1-30; sec. 30-T.34S.-R.14E., Montgomery County, KS

Elapsed time (off-bottom to canister) = 0.451
= SQRT(0.203 hrs.)
= 12.2 min.

39cc estimated lost gas

FIGURE 6.
1522' to 1524' (Riverton "rider" coal) cuttings in canister MER I
Dart Cherokee Basin Kincaid Trust #D1-30; sec. 30-T.34S.-R.14E., Montgomery County, KS

elapsed time (off-bottom to canister) = 0.371
= SQRT(0.138 hrs.)
= 8.8 min.

15cc estimated lost gas

square root of hours since cuttings were off bottom

FIGURE 7.
**Desorption Characteristics of Cuttings Samples**

Dart Cherokee basin #D1-30 Kincaid Trust, 30-T.34S.-R.14E., Montgomery County, KS

**LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS** for calculation of gas content of Mineral coal from 1213' to 1214'

\[
\text{GAS CONTENT}_{\text{coal}} = \frac{\text{total gas desorbed} - ((\text{gas content}_{\text{dark shale}}) \times (\text{weight}_{\text{dark shale}}))}{\text{weight}_{\text{coal}}}
\]

**total gas desorbed** = 279.6 ccs

**TOTAL DRY WEIGHT OF SAMPLE** = 515.56 grams

- **weight**<sub>light-colored lithologies</sub> = 9.35 grams (1.8%)
- **weight**<sub>dark shale</sub> = 462.04 grams (89.6%)
- **weight**<sub>coal</sub> = 44.17 grams (8.6%)

<table>
<thead>
<tr>
<th>sieve size</th>
<th>grams</th>
<th>% coal</th>
<th>% dark shale</th>
<th>% light-colored liths</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;0.0930&quot;</td>
<td>251.66</td>
<td>3.94%</td>
<td>95.14%</td>
<td>0.92%</td>
</tr>
<tr>
<td>&gt;0.0661&quot;</td>
<td>132.11</td>
<td>9.96%</td>
<td>88.18%</td>
<td>1.86%</td>
</tr>
<tr>
<td>&gt;0.0460&quot;</td>
<td>89.54</td>
<td>15.04%</td>
<td>81.91%</td>
<td>3.05%</td>
</tr>
<tr>
<td>&gt;0.0331&quot;</td>
<td>29.62</td>
<td>17.19%</td>
<td>78.73%</td>
<td>4.07%</td>
</tr>
<tr>
<td>&lt;0.0331&quot;</td>
<td>12.64</td>
<td>20.00%</td>
<td>75.00%</td>
<td>5.00%</td>
</tr>
</tbody>
</table>

**515.56 TOTAL**

![Figure 8](image)

**Equation solutions**

<table>
<thead>
<tr>
<th>3.0 scf/ton</th>
<th>(scf/ton)</th>
<th>(scf/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>202.8</td>
<td>202.8</td>
</tr>
<tr>
<td>1</td>
<td>192.4</td>
<td>192.4</td>
</tr>
<tr>
<td>3</td>
<td>171.4</td>
<td>171.4</td>
</tr>
<tr>
<td>5</td>
<td>150.5</td>
<td>150.5</td>
</tr>
<tr>
<td>7</td>
<td>129.6</td>
<td>129.6</td>
</tr>
<tr>
<td>10</td>
<td>98.2</td>
<td>98.2</td>
</tr>
<tr>
<td>15</td>
<td>45.9</td>
<td>45.9</td>
</tr>
<tr>
<td>17.7</td>
<td>17.7</td>
<td>17.7</td>
</tr>
</tbody>
</table>

**likely minimum gas content for coal; likely maximum gas content for dark shale**

**FIGURE 8.**
Desorption Characteristics of Cuttings Samples
Dart Cherokee basin #D1-30 Kincaid Trust, 30-T.34S.-R.14E., Montgomery County, KS

LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for calculation of gas content of Weir-Pittsburg coal from 1291' to 1292'

\[
\text{GAS CONTENT}_{\text{coal}} = \frac{\text{total gas desorbed} - (\text{gas content}_{\text{dark shale}} \times \text{weight}_{\text{dark shale}})}{\text{weight}_{\text{coal}}}
\]

total gas desorbed = 80.8 ccs

TOTAL DRY WEIGHT OF SAMPLE = 746.79 grams

\[
\begin{align*}
\text{weight}_{\text{light-colored lithologies}} & = 381.53 \text{ grams (51.1\%)} \\
\text{weight}_{\text{dark shale}} & = 26.93 \text{ grams (3.6\%)} \\
\text{weight}_{\text{coal}} & = 338.33 \text{ grams (45.3\%)}
\end{align*}
\]

\[
\begin{array}{c|c|c|c|c}
\text{sieve size} & \text{grams} & \text{\% coal} & \text{\% dark shale} & \text{\% light-colored liths} \\
\hline
>0.0930" & 256.63 & 3.90\% & 55.19\% & 40.91\% \\
>0.0661" & 258.02 & 4.00\% & 50.84\% & 45.17\% \\
>0.0460" & 167.13 & 3.04\% & 48.34\% & 48.62\% \\
>0.0331" & 42.82 & 2.54\% & 43.48\% & 53.99\% \\
<0.0331" & 22.18 & 2.00\% & 42.00\% & 56.00\%
\end{array}
\]

746.79 TOTAL

\[
\begin{align*}
\text{assumed gas content (dark shale) scf/ton} & = 6.3 \\
\text{likely minimum gas content for coal} & = 96.1 \\
\text{likely maximum gas content for dark shale} & = 400
\end{align*}
\]

Equation solutions
dark shale  
coal

0 96.1
1 81.9
2 73.8
3 67.8
4 39.4
5 25.3
6 11.1
6.3 6.3

FIGURE 9.
Desorption Characteristics of Cuttings Samples
Dart Cherokee basin #D1-30 Kincaid Trust, 30-T.34S.-R.14E., Montgomery County, KS

LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for calculation of gas content of Dry Wood coal from 1427' to 1429'

\[
\text{GAS CONTENT}_{\text{coal}} = \frac{\text{total gas desorbed} - ((\text{gas content}_{\text{dark shale}}) \times (\text{weight}_{\text{dark shale}}))}{\text{weight}_{\text{coal}}}
\]

\[
\text{total gas desorbed} = 94.5 \text{ ccs}
\]

\[
\text{TOTAL DRY WEIGHT OF SAMPLE} = 580.80 \text{ grams}
\]

\[
\begin{align*}
\text{weight}_{\text{light-colored lithologies}} &= 192.26 \text{ grams (33.1\%)} \\
\text{weight}_{\text{dark shale}} &= 344.79 \text{ grams (59.4\%)} \\
\text{weight}_{\text{coal}} &= 43.76 \text{ grams (7.5\%)}
\end{align*}
\]

\[
\begin{array}{c|c|c|c|c|c|c|c|c|c}
\text{sieve size} & \text{grams} & \% \text{coal} & \% \text{dark shale} & \% \text{light-colored liths} \\
\hline
>0.0930" & 306.40 & 8.32\% & 66.78\% & 24.90\% \\
>0.0661" & 164.64 & 8.46\% & 50.59\% & 40.95\% \\
>0.0460" & 88.68 & 4.13\% & 53.91\% & 41.96\% \\
>0.0331" & 15.85 & 3.48\% & 44.78\% & 51.74\% \\
<0.0331" & 5.23 & 2.00\% & 38.00\% & 56.00\%
\end{array}
\]

\[
580.80 \text{ TOTAL}
\]

**FIGURE 10.**
Desorption Characteristics of Cuttings Samples
Dart Cherokee basin #D1-30 Kincaid Trust, 30-T.34S.-R.14E., Montgomery County, KS

LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for calculation of gas content of Riverton coal from 1510' to 1512'

\[
\text{GAS CONTENT}_{\text{coal}} = \frac{\text{total gas desorbed} - (\text{gas content}_{\text{dark shale}} \times \text{weight}_{\text{dark shale}})}{\text{weight}_{\text{coal}}}
\]

total gas desorbed = 300.5 ccs

TOTAL DRY WEIGHT OF SAMPLE = 970.00 grams

weight_{light-colored lithologies} = 69.04 grams (7.1%)

weight_{dark shale} = 818.51 grams (84.4%)

weight_{coal} = 82.45 grams (8.5%)

\begin{array}{|c|c|c|c|}
\hline
\text{sieve size} & \text{grams} & \% \text{coal} & \% \text{dark shale} & \% \text{light-colored liths} \\
\hline
>0.0930'' & 537.23 & 10.04\% & 83.70\% & 6.26\% \\
>0.0661'' & 263.00 & 6.83\% & 85.42\% & 7.75\% \\
>0.0460'' & 133.92 & 6.95\% & 84.75\% & 8.30\% \\
>0.0331'' & 27.91 & 3.89\% & 85.56\% & 10.56\% \\
<0.0331'' & 7.95 & 2.00\% & 86.00\% & 12.00\% \\
\hline
\end{array}

970.00 TOTAL

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure11.png}
\caption{FIGURE 11.}
\end{figure}
Desorption Characteristics of Cuttings Samples
Dart Cherokee basin #D1-30 Kincaid Trust, 30-T.34S.-R.14E., Montgomery County, KS

LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for calculation of gas content of Riverton "rider" coal from 1522' to 1524'

\[
\text{GAS CONTENT}_{\text{coal}} = \frac{\text{total gas desorbed}}{\text{weight}_{\text{coal}}} - \left( \frac{\text{gas content}_{\text{dark shale}} \times \text{weight}_{\text{dark shale}}}{\text{weight}_{\text{coal}}} \right)
\]

total gas desorbed = 107.6 ccs

TOTAL DRY WEIGHT OF SAMPLE = 227.35 grams

weight_{light-colored lithologies} = 57.34 grams (25.2%)
weight_{dark shale} = 145.98 grams (64.2%)
weight_{coal} = 24.02 grams (10.6%)

<table>
<thead>
<tr>
<th>sieve size</th>
<th>grams</th>
<th>% coal / % dark shale / % light-colored liths</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;0.0930&quot;</td>
<td>110.92</td>
<td>9.31% / 62.66% / 28.03%</td>
</tr>
<tr>
<td>&gt;0.0660&quot;</td>
<td>74.00</td>
<td>13.16% / 66.58% / 20.25%</td>
</tr>
<tr>
<td>&gt;0.0460&quot;</td>
<td>30.60</td>
<td>8.76% / 65.99% / 25.25%</td>
</tr>
<tr>
<td>&gt;0.0331&quot;</td>
<td>8.00</td>
<td>11.22% / 56.59% / 32.20%</td>
</tr>
<tr>
<td>&lt;0.0331&quot;</td>
<td>3.82</td>
<td>10.00% / 65.00% / 25.00%</td>
</tr>
</tbody>
</table>

227.35 TOTAL

Equation solutions

\[
\begin{align*}
\text{dark shale} & : 0 & 143.5 \\
\text{coal} & : 1 & 137.4 \\
& : 3 & 125.3 \\
& : 5 & 113.1 \\
& : 7 & 100.9 \\
& : 10 & 82.7 \\
& : 15 & 52.3 \\
& : 20 & 21.9 \\
& : 20.3 & 20.3
\end{align*}
\]

FIGURE 12.
Desorption Characteristics of Cuttings Samples  
Dart Cherokee basin #D1-30 Kincaid Trust, 30-T.34S.-R.14E., Montgomery County, KS

LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for all samples

<table>
<thead>
<tr>
<th>UNIT</th>
<th>coal in sample</th>
<th>scf/ton w/ shale @ 3 scf/ton</th>
<th>maximum scf/ton</th>
<th>minimum scf/ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral</td>
<td>9%</td>
<td>171.4</td>
<td>202.8</td>
<td>17.7</td>
</tr>
<tr>
<td>Weir-Pittsburg</td>
<td>4%</td>
<td>53.6</td>
<td>96.1</td>
<td>6.3</td>
</tr>
<tr>
<td>Dry Wood</td>
<td>8%</td>
<td>45.6</td>
<td>69.2</td>
<td>7.8</td>
</tr>
<tr>
<td>Riverton</td>
<td>9%</td>
<td>87.0</td>
<td>116.8</td>
<td>10.7</td>
</tr>
<tr>
<td>Riverton &quot;rider&quot;</td>
<td>11%</td>
<td>125.3</td>
<td>143.5</td>
<td>20.3</td>
</tr>
</tbody>
</table>

**FIGURE 13.**
Desorption Characteristics of Cuttings Samples
based on total weight of gas-generating lithologies (i.e., coal and dark shale) in sample
Dart Cherokee Basin #D1-30 Kincaid Trust;
30-T.34S.-R.14E., Montgomery County, KS

FIGURE 14.