



FLY ASH RESISTIVITY WITH INJECTED REAGENTS AND PREDICTED IMPACTS ON ELECTROSTATIC PRECIPITATORS

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EXECUTIVE SUMMARY

Electrostatic precipitators (ESP's), which are particulate collectors, are now used as part of the flue gas scrubbing strategy. In these combined systems, a particulate reagent is injected into the flue gas ahead of the ESP, to either neutralize or adsorb a gaseous pollutant. Then the ESP must remove the fly ash from fuel combustion, plus the injected particulate reagent/reactant.

The primary parameter in ESP performance is the particulate resistivity. Particulate resistivity is a measure of how well the particulate, when deposited on the ESP collecting electrodes, conducts electricity to ground. Variations in resistivity, from optimum to extremely high, can change ESP particulate emissions by significant amounts. Therefore, in the practice of injecting reagents into the flue gas and capturing these reagents in the ESP, we must be very concerned with the impacts of injected reagent on combined particulate resistivity. This single parameter will have a greater impact on ESP performance than all others combined.

This paper is a study of the impacts on resistivity from several different sorbents, and varying concentrations of sorbent injection. The paper will also discuss predictions of ESP particulate emissions with sorbent injection. However, this general discussion is not a substitute for a specific study on each ESP, prior to installation of new sorbent injection systems. Each sorbent study is presented as two page section that could be excerpted and used independently.

RESISTIVITY INTERPRETATION

Laboratory resistivity (OHM-CM) of a dust is the ratio of the applied electric potential across the dust layer to the induced current density. The value of the resistivity for a dust sample depends upon a number of variables, including dust chemistry, dust porosity, dust temperature, composition of gaseous environment (i.e. gas moisture), magnitude of applied electric field strength, and test procedure.

In working with electrostatic precipitators (ESP's), resistivities are encountered in the range from about 1E4 to 1E14 OHM-CM. The optimum value for resistivity is generally considered to be in the range of 1E8 to 1E11 OHM-CM. In this range the dust is conductive enough that charge does not build-up in the collected dust layer and insulate the collecting plates. Additionally, the dust does not hold too much charge and is adequately cleaned from the collecting plates by normal rapping. If resistivity is in the range 1E12 to 1E14 OHM-CM, it is considered to be high resistivity dust. This dust is tightly held to the collecting plates, because the dust particles do not easily conduct their charge to ground. This insulates the collecting plates and high ESP sparking levels result (also poor ESP collection efficiencies). Conversely, if the dust is low resistivity, 1E4 to 1E7 OHM-CM, the dust easily conducts its charge to the grounded collecting plates. Then, there is not residual charge on the dust particles to hold them on the plates. Thus, these particles are easily dislodged and re-entrain back into the gas stream. ESP gas velocities are generally designed in the 2.5-3.5 FT/S range, if high carbon particles are to be collected.

In looking at resistivity data, the resistivity "curves" generally peak out in the range of 280-360° F. On the high side of the peak, thermal conduction effects cause the resistivity to decrease as temperature increases. On the cold side of the resistivity peak, condensation of moisture on the surface of the particulate causes the resistivity to decrease as well.

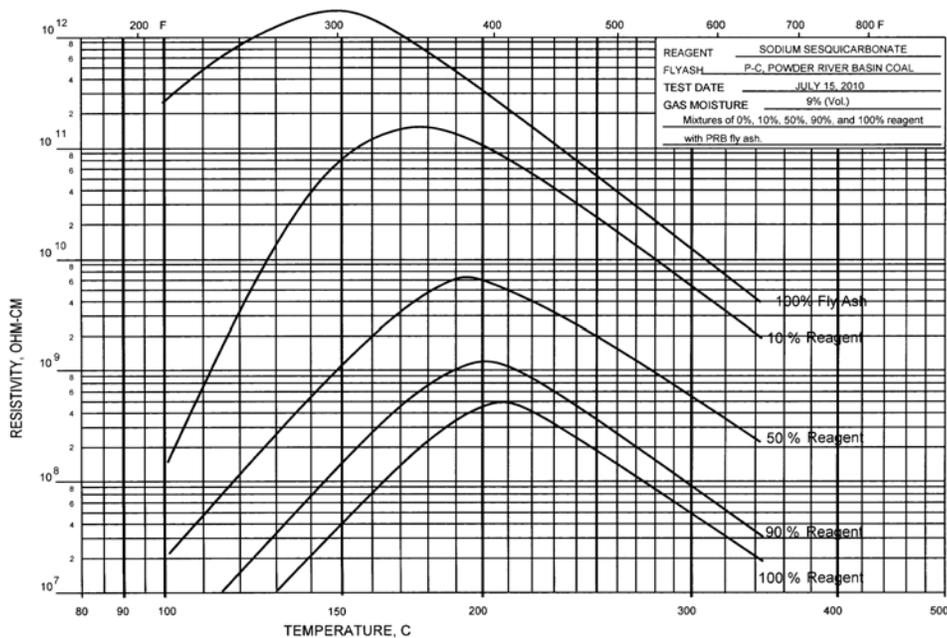
One note on the high sulfur cases; the laboratory resistivity testing was done strictly with humidity for surface conditioning. So these measurements in this report are for the bulk material only. In the actual flue gas there will be surface conditioning from sulfuric acid, to reduce the particulate resistivity down to even lower values than shown in this report. However, in most cases, the fly ash from high sulfur coal contains relatively low levels of dielectric (i.e. silica+aluimina+CaO). So there is never a situation where we have anything but a good resistivity predicted for any of the high sulfur cases. Therefore, no matter what chemical we inject with high sulfur coal, we have good resistivity before and good resistivity after injection.

TRONA INJECTION

The proper chemical name for trona is sodium sesquicarbonate ($\text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot 2\text{H}_2\text{O}$). Trona is a naturally formed ore which is mined and then milled for injection. Of primary importance to resistivity measurements, is the fact that this material contains sodium. In the ESP industry, sodium compounds have been used for many years as additives to solve resistivity problems. In these ESP uses, the sodium compounds have been injected on the coal belt, dry into the flue gas, and wet into the flue gas. The purpose was to introduce sodium bearing materials into the dust layer deposited on the collecting plates of the ESP.

In recent years, trona is being injected as a reagent for gaseous scrubbing purposes. But at the same time, this added particulate must be collected by the ESP. To better understand the impacts of this injection, resistivity studies were undertaken with both Powder River Basin (PRB) sub-bituminous fly ash and Eastern high sulfur bituminous fly ash. Several hypothetical injection rates were tested for both types of fly ash. The results of resistivity tests for PRB coal are shown on Figures T1;

Figure T1 – Powder River Basin Coal

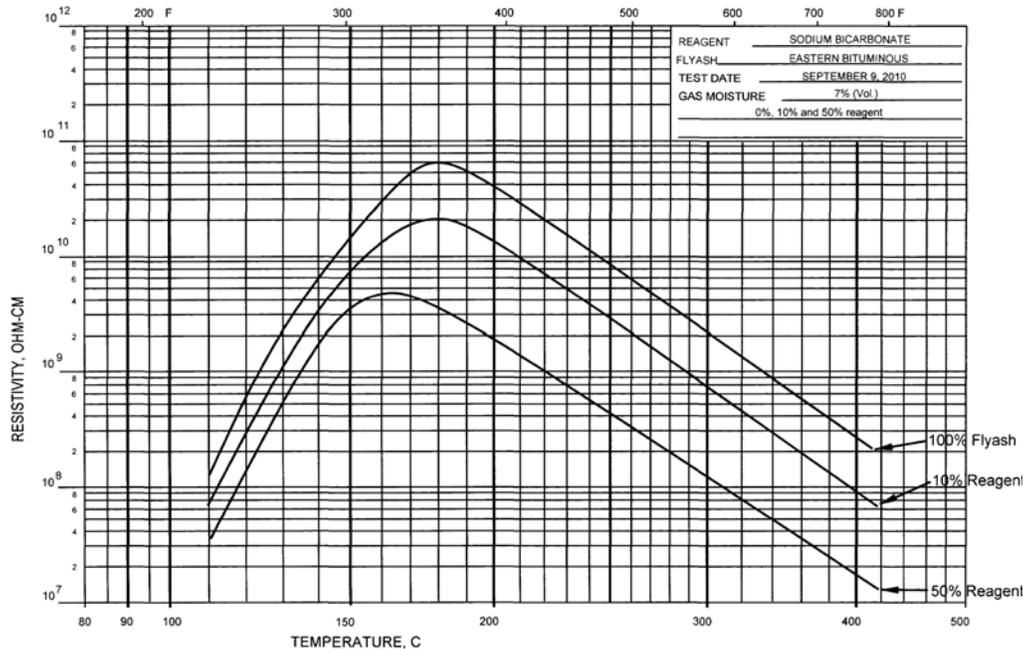


There are several things to note on Figure T1. First the resistivity of the 100% PRB fly ash was in the high range (i.e. $>1\text{E}12$ OHM-CM), which on its own would cause difficulty for ESP performance. Then tests of 90 and 100% trona showed the resistivity to “peak out” at $1\text{E}9$ OHM-CM or lower. This is a low/good value for electrostatic precipitation. So as expected, the pure or near pure sodium reagent is very low in resistivity. With any case of very high injection rates vs. fly ash rate, there would be a huge improvement in resistivity/ESP performance.

However, the typical injection rate for trona injection is in the 10% trona to 90% fly ash range. In this case, the combined fly ash/reagent resistivity drops by about one order of magnitude. This is a significant improvement in resistivity, and would make the ESP emit lower particulate emissions. This prediction takes into account that the inlet loading to the ESP would be 10% higher. Inlet loading is a much less powerful impactor on ESP performance than resistivity. This is especially true in this case, when the particle size of the injected reagent is created from milling. It is typical for the particle size from pulverized coal firing to be much finer. This is because the particle size of fly ash is created by milling and then burning off of the carbon in the coal. ESP's are known to be particle size dependent, and large particles are collected much easier than fine particles.

Fly ash from high sulfur Eastern bituminous coal is quite different in resistivity from PRB fly ash. Figure T2 shows tests for the Eastern coal fly ash;

Figure T2



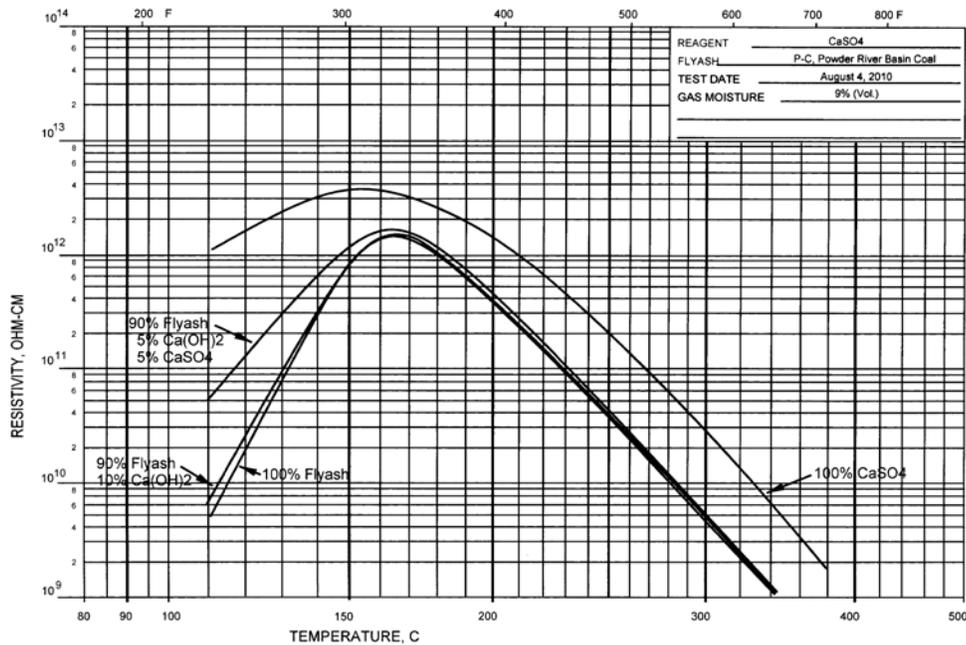
On Figure T2, we can note that the bulk resistivity of 100% high sulfur Eastern coal fly ash has a good resistivity on its own. The addition of the typical injection quantity of 10% trona does serve to reduce resistivity, but resistivity is good in both cases. So there is not really an improvement in resistivity here. We go from good to good. In this case, the ESP must be studied specifically to see if the increase in inlet dust loading would cause a “bogging down” of the inlet fields of the ESP. This will be dependent on ESP size, inlet field electrode geometry, and ESP rapping density. There is potential that injection could cause higher particulate emissions, if the ESP is marginal in size or design.

CALCIUM HYDROXIDE INJECTION

The chemical formula of calcium hydroxide is $\text{Ca}(\text{OH})_2$. Of primary importance to resistivity measurements, is that this material contains calcium. In the ESP industry, calcium compounds (CaO , CaSO_4 , CaCO_3) have been observed for many years to be highly resistive. In these ESP uses, the resistivity of the calcium bearing compounds has been controlled by injecting moisture and operating on the cold side of the resistivity peak.

In recent years, the $\text{Ca}(\text{OH})_2$ is being injected as a reagent for gaseous scrubbing purposes. But at the same time this added particulate must be collected by the ESP. Note that at the ESP, some of the calcium may exist as reagent, $\text{Ca}(\text{OH})_2$, and some as reactant, CaSO_4 . To better understand the impacts of this injection, resistivity studies were undertaken with both Powder River Basin sub-bituminous fly ash and Eastern high sulfur bituminous fly ash. Several hypothetical injection rates were tested for both types of fly ash. The results of resistivity tests for PRB coal are shown on Figures C1;

Figure C1



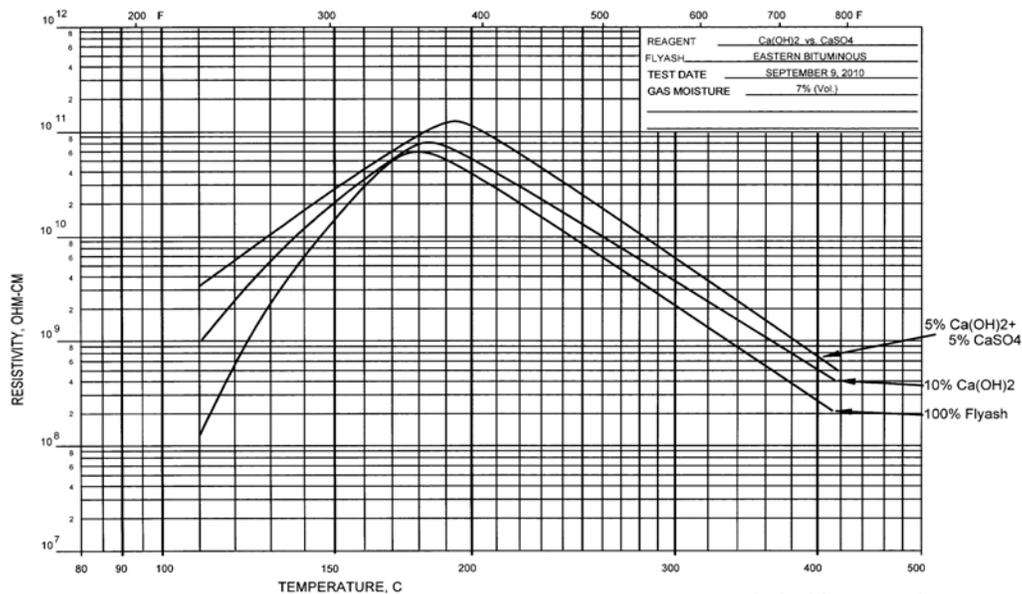
There are several things to note on Figure C1. First the resistivity of the 100% PRB fly ash was in the high range (i.e. $>1\text{E}12$ OHM-CM), which on its own would cause difficulty for ESP performance. Then tests of 100% $\text{Ca}(\text{OH})_2$ showed the resistivity to “peak out” even higher at $4\text{E}12$ OHM-CM. This is a high/bad value for electrostatic precipitation. So as expected, the pure calcium reagent is very high in resistivity. With any cases of very high injection rates vs. fly ash rate, there would be a negative impact on resistivity/ESP performance.

However, the typical injection rate for $\text{Ca}(\text{OH})_2$ injection is in the 10% reagent to 90% fly ash range. In this more dilute case, the combined fly ash/reagent resistivity is hardly impacted

by the injection. This means that really the only impact on the ESP would be from a 10% higher inlet dust loading coming to the ESP. Inlet loading is a much less powerful impactor on ESP performance than resistivity. This is especially true in this case, when the particle size of the injected reagent is created from milling. It is typical for the particle size from pulverized-coal firing to be much finer. This is because the particle size of fly ash is created by milling and then burning off of the carbon in the coal. Therefore the Ca(OH)_2 impact in this case would depend on ESP design and sizing. If the ESP is conservative (i.e. properly designed for high resistivity), the prediction would be very little increase in particulate emissions in this case.

Fly ash from high sulfur Eastern bituminous coal is quite different in resistivity from PRB fly ash. Figure C2 shows tests for the Eastern coal fly ash;

Figure C2



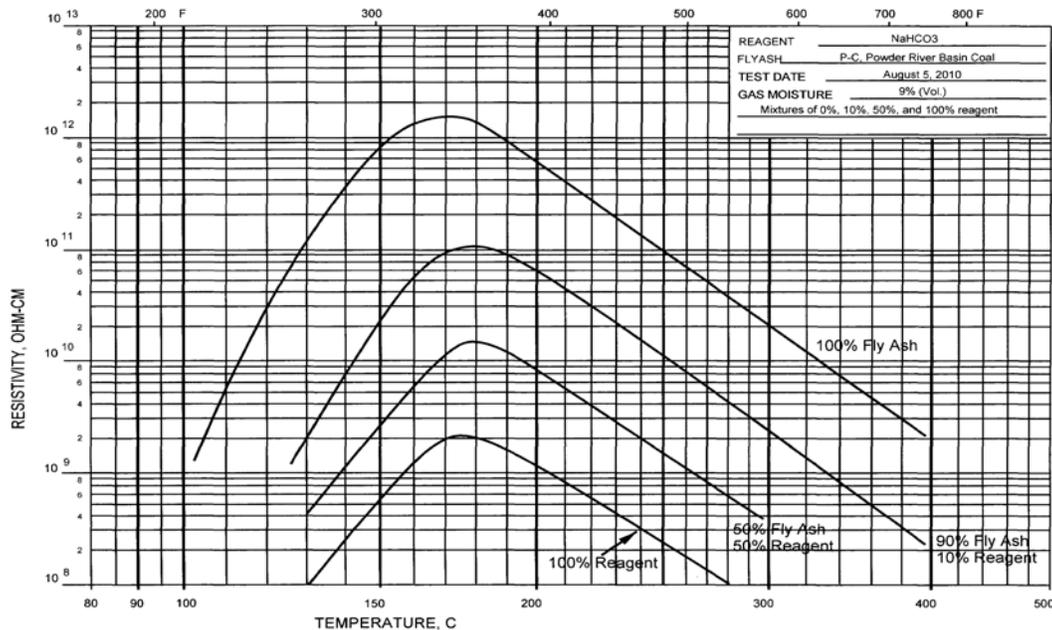
On Figure C2, we can note that the bulk resistivity of 100% high sulfur Eastern coal fly ash has a good resistivity on its own. The addition of the typical injection quantity of 10% Ca(OH)_2 does increase resistivity, by up to ½ order of magnitude. This does not increase resistivity to a severe condition, but it is a small move in the poorer direction. At the same time the 10% increase in inlet dust loading is also a small move in a poorer direction. So there is some possibility of an increase in particulate emission. In this case, the ESP must be studied specifically to see if the increase in inlet dust loading would cause a “bogging down” of the inlet fields of the ESP. This will be dependent on ESP size, inlet field electrode geometry, and ESP rapping density. There is potential that injection could cause higher particulate emissions, if the ESP is marginal in size or design.

SODIUM BICARBONATE INJECTION

The chemical formula of sodium bicarbonate is NaHCO_3 . Of primary importance to resistivity measurements, is the fact that this material contains sodium. In the ESP industry, sodium compounds have been used for many years as additives to solve resistivity problems. In these ESP uses, the sodium compounds have been injected on the coal belt, dry into the flue gas, and wet into the flue gas. The purpose was to introduce sodium bearing materials into the dust layer deposited on the collecting plates of the ESP.

In recent years, the sodium bicarbonate is being injected as a reagent for gaseous scrubbing purposes. But at the same time this added particulate must be collected by the ESP. To better understand the impacts of this injection, resistivity studies were undertaken with both Powder River Basin sub-bituminous fly ash and Eastern high sulfur bituminous fly ash. Several hypothetical injection rates were tested for both types of fly ash. The results of resistivity tests for PRB coal are shown on Figures B1;

Figure B1



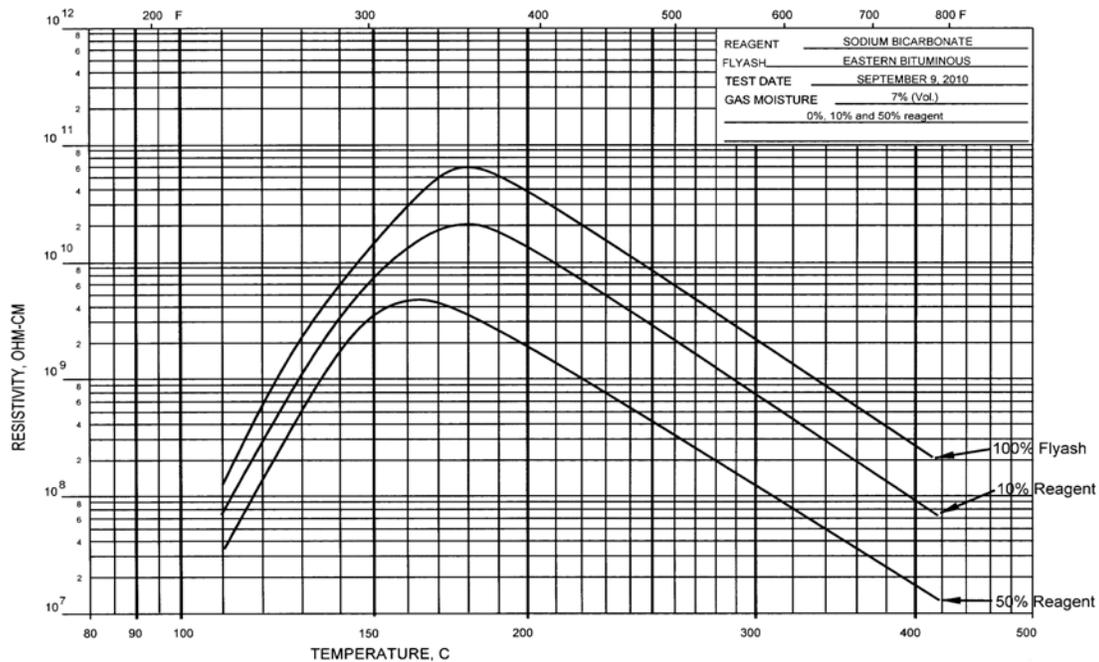
There are several things to note on Figure B1. First the resistivity of the 100% PRB fly ash was in the high range (i.e. $>1\text{E}12$ OHM-CM), which on its own would cause difficulty for ESP performance. Then tests of 100% NaHCO_3 showed the resistivity to “peak out” at $2\text{E}9$ OHM-CM or lower. This is a low/good value for electrostatic precipitation. So as expected, the pure or near pure sodium reagent is very low in resistivity. With any cases of very high injection rates vs. fly ash rate, there would be a huge improvement in resistivity/ESP performance.

However, the typical injection rate for NaHCO_3 injection is in the 10% to 90% fly ash range. In this case, the combined fly ash/reagent resistivity drops by about one order of

magnitude. This is a significant improvement in resistivity, and would make the ESP work better in terms of particulate emissions. Note that this prediction takes into account that the inlet loading to the ESP would be 10% higher. Inlet loading is a much less powerful impactor on ESP performance, than resistivity. This is especially true in this case, when the particle size of the injected reagent is created from milling. It is typical for the particle size from pulverized-coal firing to be much finer. This is because the particle size of fly ash is created by milling and then burning off of the carbon in the coal.

Fly ash from high sulfur Eastern bituminous coal is quite different in resistivity from PRB fly ash. Figure B2 shows tests for the Eastern coal fly ash;

Figure B2



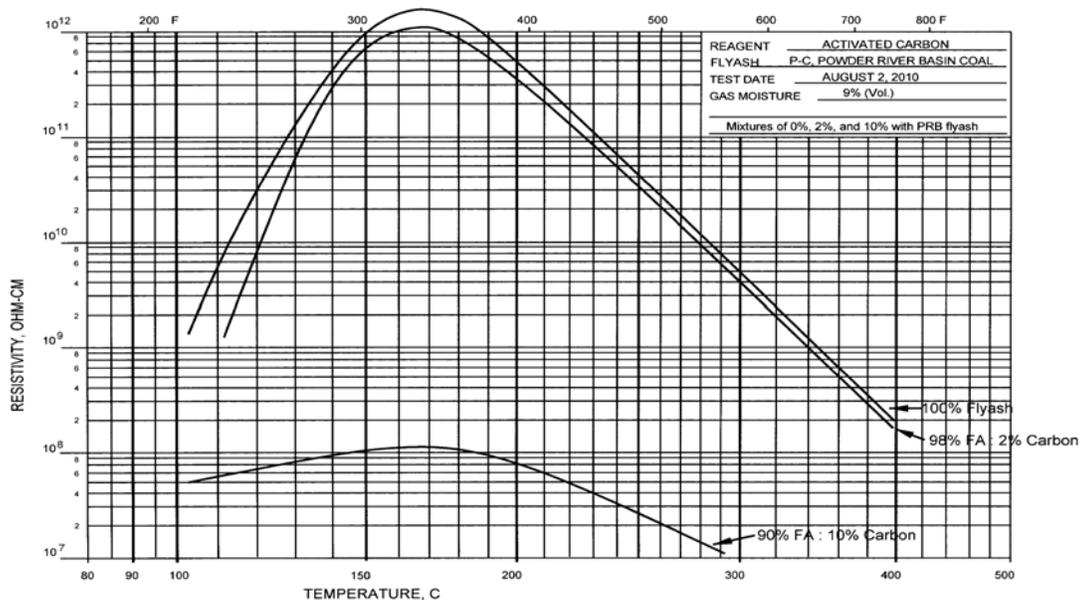
On Figure B2, we can note that the bulk resistivity of 100% high sulfur Eastern coal fly ash has a good resistivity on its own. The addition of the typical injection quantity of 10% sodium bicarbonate does serve to reduce resistivity, but resistivity is good in both cases. So there is not really an improvement in resistivity here. We go from good to good. In this case, the ESP must be studied specifically to see if the increase in inlet dust loading would cause a “bogging down” of the inlet fields of the ESP. This will be dependent on ESP size, inlet field electrode geometry, and ESP rapping density. There is potential that injection could cause higher particulate emissions, if the ESP is marginal in size or design

ACTIVATED CARBON INJECTION

The chemical formula of this reagent would be C. Of primary importance to resistivity measurements, is the fact that this material contains carbon. In the ESP industry, carbon has been encountered on many applications (oil firing, coal stoker firing, wood waste firing, etc.). In these ESP uses, the carbon has been observed to give very low resistivity. However, each of these ESP applications has carbon levels in the 20-90% range.

In recent years, the carbon is being injected as a reagent for mercury scrubbing purposes. But at the same time this added particulate must be collected by the ESP. To better understand the impacts of this injection, resistivity studies were undertaken with both Powder River Basin sub-bituminous fly ash and Eastern high sulfur bituminous fly ash. Several hypothetical injection rates were tested for both types of fly ash. The results of resistivity tests for PRB coal are shown on Figures A1;

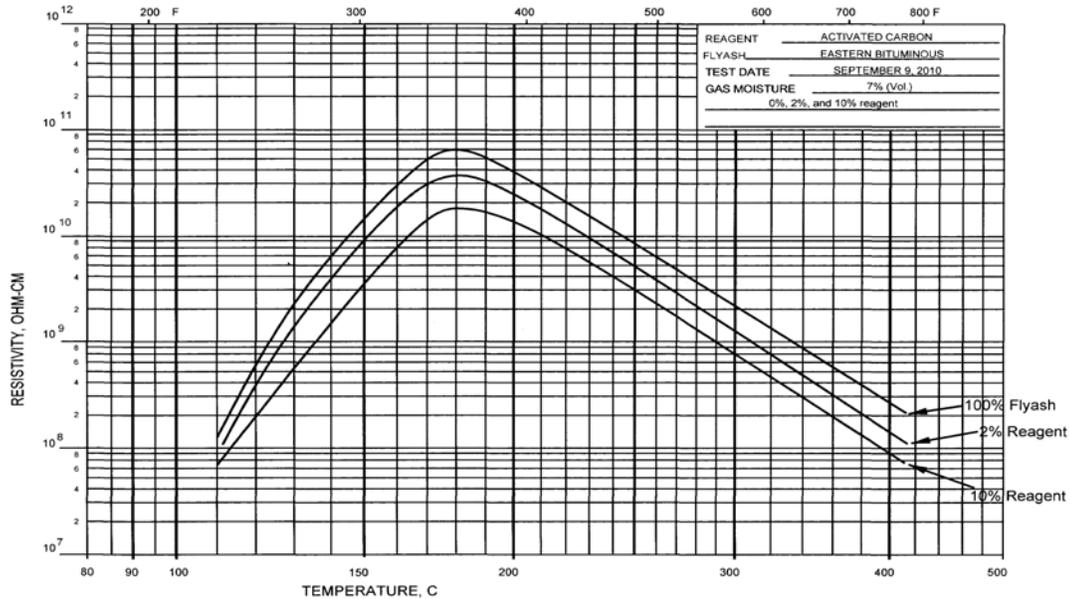
Figure A1



The typical injection rate for carbon injection is in the range of 2-10% carbon to 98-90% fly ash range. In the case of 2% carbon injection, the combined fly ash/reagent resistivity is unchanged. In the case of 10% carbon, the resistivity drops by four orders of magnitude. This is a significant improvement in resistivity and would make a large ESP, designed for high resistivity, work better in terms of particulate emissions. In both cases, there is either a no change or prediction of ESP performance improvement for these cases. Note that this prediction takes into account that the inlet loading to the ESP would be 10% higher. Inlet loading is a much less powerful impactor on ESP performance than resistivity..

Fly ash from high sulfur Eastern bituminous coal is quite different in resistivity from PRB fly ash. Figure A2 shows tests for the Eastern coal fly ash;

Figure A2



On Figure B2, we can note that the bulk resistivity of 100% high sulfur Eastern coal fly ash has a good resistivity on its own. The addition of the typical injection quantity of 2-10% carbon does serve to reduce resistivity, but resistivity is good in both cases. So there is not really an improvement in resistivity here. We go from good to good. In this case, the ESP must be studied specifically. This is because there would typically be a very small ESP for high sulfur coal. Also some of the older designs might have an extreme high velocity present. Carbon particles will have a tendency to re-entrain, and high velocity in the ESP would make the situation sensitive to velocity. There is potential that carbon injection could cause higher particulate emissions, if the ESP is marginal in size or gas velocity (and the higher levels of carbon, 10%, are injected).