ABSTRACT

The product gases generated by coal gasification systems contain high concentrations of CO and, characteristically, have relatively high carbon activities. Accordingly, carbon deposition and metal dusting can potentially degrade the operation of such gasifier systems. Therefore, the product gas compositions of eight representative gasifier systems were examined with respect to the carbon activity of the gases at temperatures ranging from 480 to 1090°C (900 to 2000°F). The composition of the product gas is such that high carbon activities are guaranteed when the gas is cooled after exiting the gasifier. Assuming that all of the gas components are in thermodynamic equilibrium, calculations show that carbon activities greater than unity would result at temperatures below 800 to 870°C (1470 to 1600°F) in the case of air-blown gasifiers and at considerably higher temperatures in the case of oxygen-blown gasifiers containing greater than 54 vol % CO.

Phase stability calculations indicated that Fe_3C is stable only under very limited thermodynamic conditions and with certain kinetic assumptions and that FeO and $Fe_{0.877}S$ tend to form instead of the carbide. As formation of Fe_3C is a necessary step in the metal dusting of steels, there are numerous gasifier environments where this type of carbon-related degradation will not occur, particularly under conditions associated with higher oxygen and sulfur activities. These calculations also indicated that the removal of H_2S by a hot-gas cleanup system may have less effect on the formation of Fe_3C in air-blown gasifier environments, where the iron oxide phase can exist and is unaffected by the removal of sulfur, than in oxygen-blown systems, where iron sulfide provides the only potential barrier to Fe_3C formation. However, overall, the adoption of hot-gas desulfurization strategies will probably increase carbon-related degradation, since H_2S is removed in a temperature regime where carbon deposition and metal dusting are possible.

Use of carbon- and/or low-alloy steels dictates that the process gas composition be such that Fe_3C cannot form if the potential for metal dusting is to be eliminated. Alternatively, process modifications could include the reintroduction of hydrogen sulfide (to poison the carbon deposition reaction or to form iron sulfide at the expense of Fe_3C), cooling the gas to perhaps as low as 400°C (750°F), and/or steam injection. If higher-alloy steels (those that will form and maintain a protective chromia film on the surface) are used, a hydrogen sulfide-free gas (or a gas with very low hydrogen sulfide content at higher temperatures) may be processed without concern about carbon deposition and metal dusting.

It was concluded that testing, preferably under prototypical coal gasification conditions, will be needed to experimentally validate the thermodynamic calculations and assumptions about kinetic limitations that are key to developing a predictive capability with respect to carbon formation and metal dusting.