# Diesel Desulfurization For High Temperature Fuel Cells

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Carbonate fuel cells are new generation of power plants that provide electricity at very high efficiency and low environmental emissions. FCE's "direct carbonate fuel cell" operates on a variety of hydrocarbon fuels such as natural gas, biogas, coal gas, diesel and LPG. Conventionally, an external reformer is used to supply hydrogen rich gas to fuel cell. FuelCell Energy's DFC$^{TM}$ technology has adopted an internal reforming approach that eliminates the need for an external reformer, resulting in increased efficiency, compactness, better thermal management and lower cost.

DFC operation on natural gas, peak shaving gas, LPG, digester gas, syngas, coal bed methane, and liquid fuels such as diesel, methanol and ethanol has been already demonstrated. Fuel clean-up and fuel processing operation varies based on the nature of fuel. However, the fuel thus supplied to the fuel cell has a two-step refinement approach. Step 1 involves fuel clean up system to remove impurities such as sulfur, halides, solid particulates, aromatic hydrocarbons, and oxygen. The second step is pre-reforming desulfurized fuel to knock out higher hydrocarbons in order to eliminate coke formation during reforming inside the fuel cell. Methane-rich gas obtained from pre-reformer is thus fed into fuel cell for internal reforming to produce hydrogen in DFC stacks which in turn is electrochemically converted to water, thereby producing DC power. At each stage of this operation, catalysts are used to facilitate production of desirable fuel cell fuel.

Fuel clean-up considerations vary with type of fuel and its constituents. The nature of impurities and their concentration will be considered to design suitable clean-up processor for each type of fuel for DFC applications. Table 1 indicates various fuels specification including type of impurities and their levels for designing clean-up processor. The impurities present in fuels will impact the performance of reforming catalysts, cell performance and overall life of fuel cell. Ni-based catalysts are used for internal reforming and prereforming of higher hydrocarbons. Nickel catalysts are sensitive for sulfur, chloride and particulate poisoning, thus, require impurity-free fuel for fuel cell applications. The tolerance level of these impurities on both catalyst and fuel cell components are significantly lower than conventional fuel processing operations. Also, the tolerance level is based on the type of impurity. Although worldwide standards favor a gradually lowering sulfur and other impurity levels in transportation fuels, it is necessary to further reduce the sulfur levels in fuel cells to sub-ppm levels prior to use in fuel cell power plants. Depending on the nature of fuel and impurity levels, an appropriate fuel clean-up process with suitable adsorbents/catalysts is required in DFC balance of power plant operation.

FCE has designed multi-fuel clean-up processor to meet DFC power plant tolerances for each type of impurities present in the fuel. These designs were based on either catalytic or adsorbent and selected based on type of fuel and impurity. Multi-fuels processed at FCE's tests have been able to reduce impurity levels (sulfur, halides, particulates and metals) to less than sub ppm levels. This presentation will discuss FCE's experience with multi-fuel clean-up considerations and primarily focusing on desulfurization of diesel and LPG fuels.

Table1: Typical Fuels Composition: Desulfurization Clean-up Consideration

| Compostion | Natural Gas | Coal Bed Methane | Digester Gas | Typical Landfill Gas | KRW Gasifier Coal Gas (Air as Oxidant) | BGL Gasifier Coal Gas (Oxygen as Oxidant) | Ethanol | Propane | Diesel |
|---|---|---|---|---|---|---|---|---|---|
| Methane, vol% | 80-100 | 91 | 60.7 | 40-55 | 0.3 | 6.1 | - | - | - |
| Hydrogen | None | | - | - | 19.0 | 21.0 | - | - | - |
| Carbon Dioxide, vol% | 0-3 | 3.1 | 34.9 | 35-50 | 13.5 | 4.7 | - | - | - |
| Carbon Monoxide, vol% | - | None | - | - | 9.9 | 39.5 | - | - | - |
| Nitrogen, vol% | 0-3 | 5.0 | 3.2 | 0-20 | 41.4 | 2.8 | - | - | - |
| Oxygen, vol% | 0-0.2 | 0.1 | 0.9 | 0.5-1.0 | - | - | - | - | - |
| Higher Hydrocarbons | 0-10 | 1.0 | - | - | - | - | 1-3 | 1.0 | $C_{15}H_{27}$ (Avg. Mol. wt) |
| Ethanol, vol% | - | - | - | - | - | - | 10-25 | - | - |
| Propane, vol% | | | - | - | - | - | | 99 | - |
| Impurities (ppm): | | | | | | | | | |
| Sulfur | 0-12 | 0.5 | 0.3 | 200 | 0.4 | 10 | ~100 | 100-200 | >5000 |
| Chlorine | None | 0.25 | - | 0.03 | - | - | | - | - |
| Heating Value | High | High | Medium | Medium | Medium | Medium | | High | High |