

MEMORANDUM

State of Alaska

Department of Environmental Conservation
Division of Air and Water Quality - Air Quality Maintenance

TO: John Stone, Chief

DATE: March 24, 1998

FILE: 74.05.02

FROM: John Kuterbach
Air Quality Maintenance

SUBJECT: Maximum SO₂ Concentration
from the combustion of #2
diesel fuel

EPA in their Title V permit reviews is requiring the department to demonstrate that limiting fuel sulfur to 0.5% will ensure compliance with our 500 ppmv SO₂ limit. This memorandum sets forth engineering calculations which demonstrate that combustion of #2 diesel fuel containing up to 0.5% sulfur will always comply with the 500 ppmv SO₂ limit regardless of the engine involved. I recommend that we reference these calculations in future "statements of basis" that we send to EPA with our draft operating permits.

Summary

This engineering calculation examined the stoichiometric combustion of #2 diesel fuel and calculated the maximum sulfur dioxide content of the flue gases. Typically, combustion of #2 diesel fuel can produce up to 338 ppmv SO₂ in the flue gas. Although this figure varies proportionally with the carbon content of the diesel fuel, the figure will never exceed the 500ppm limit.

I conclude that combustion of #2 diesel fuel with air will always comply with the 500ppmv emission limit. The ASTM specification for #2 diesel fuel limits sulfur to 0.5% or less.

Assumptions

All constituents of the fuel are burned proportionally

Any excess air typical of combustion would tend to dilute the SO₂ concentration in the flue gas, therefore only theoretical air is considered.

#2 diesel fuel is composed of Carbon, Hydrogen, Sulfur, and negligible amounts of Water and ash.

Ignore the water because the standard is a dry standard and the water will drop out of any calculations.

Ignore the ash as negligible unless the study predicts an SO₂ concentration greater than 450 ppm.

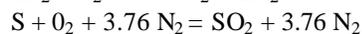
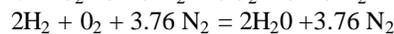
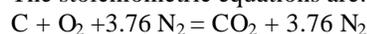
Typical #2 diesel fuel is composed of 87% Carbon, 12.5% Hydrogen, and 0.5% Sulfur

Calculations.

Using normal air for combustion (79% N₂ and 21% O₂):

For each lb-mole of Oxygen in Air, there is 3.76 lb-mole Nitrogen (1 lb-mole O₂) = (0.79/0.21) = 3.76 lb-mole N₂

The stoichiometric equations are:



To calculate the dry exhaust gases (CO₂, N₂, SO₂) the following equations are used:

moles CO₂ = (lb C) x (1 lb-mole C/12.01 lb C) x (1 lb-mole CO₂/1 lb mole C)

moles N₂ = (lb C) x (1 lb-mole C/12.01 lb C) x (3.76 lb-mole N₂/lb-mole C)

$$\begin{aligned}
 &+ (\text{lb H}_2) \times (1 \text{ lb-mole H}_2/2.016 \text{ lb H}_2) \times (3.76 \text{ lb-mole N}_2/2 \text{ lb-mole H}_2) \\
 &+ (\text{lb S}) \times (1 \text{ lb-mole S}/32.06 \text{ lb S}) \times (3.76 \text{ lb-mole N}_2/\text{lb-mole S}) \\
 \text{moles SO}_2 = &+ (\text{lb S}) \times (1 \text{ lb-mole S}/32.06 \text{ lb S}) \times (\text{lb-mole SO}_2/1 \text{ lb-mole S})
 \end{aligned}$$

Condensing these equations leaves:

$$\begin{aligned}
 \text{moles CO}_2 &= \text{lb C}/12.01 \\
 \text{moles N}_2 &= 3.76 \times [(\text{lb C}/12.01) + (\text{lb H}_2/4.032) + (\text{lb S}/32.06)] \\
 \text{moles SO}_2 &= \text{lb S}/32.06
 \end{aligned}$$

Then, by Avogadro's Law and the definition of mole:

$$\text{ppmv SO}_2 = 1,000,000 \times [\text{moles SO}_2/(\text{moles CO}_2 + \text{moles N}_2 + \text{moles SO}_2)]$$

Results

Using 100 pounds of fuel as a basis, we examined the following three cases:

| Case | Pounds in Fuel | | |
|------|----------------|----------|--------|
| | Carbon | Hydrogen | Sulfur |
| 1 | 87 | 12.5 | 0.5 |
| 2 | 96 | 3.5 | 0.5 |
| 3 | 78 | 21.5 | 0.5 |

Case 1 is the normal case, Case 2 increases carbon by 10 percent, and Case 3 decreases carbon by 10 percent.

| | Case 1 | Case 2 | Case 3 |
|-----------------------|--------|--------|--------|
| moles CO ₂ | 7.24 | 7.99 | 6.49 |
| moles N ₂ | 38.94 | 33.36 | 44.51 |
| moles SO ₂ | 0.0156 | 0.0156 | 0.0156 |
| Total Dry Moles | 46.196 | 41.366 | 51.016 |
| ppmv SO ₂ | 338 | 377 | 306 |

Conclusion

The above calculations show that #2 diesel fuel combusted with air will always comply with the 500 ppmv SO₂ limit. The calculations use the conservative assumptions of complete combustion and no excess air. The real-world includes partial combustion and excess air, both of which would tend to dilute the SO₂ concentration in the exhaust effluent.

The equations above can be used as an initial screening for other petroleum fuels even with a higher sulfur content or significant ash.

If you agree this memorandum has value, please share it with the rest of the AQM staff.