Appendix F

Small Refiner Emissions Offsets

Calculation of Emissions Offset Requirements for the Small Refiner Provisions

Introduction

Section 2272 specifies that for each barrel of gasoline produced by a small refiner to the small refiner standards, the following excess emissions would have to be offset: 0.0206 pounds of exhaust THC per barrel, 0.0322 pounds of NOx per barrel, and potency-weighted toxics (PWT) equivalent to 0.0105 pounds per barrel of benzene. The proposed amendments to secion 2282 (Aromatic Hydrocarbon Content of Diesel Fuel) describe the mechanism whereby a small refiner provides offsets for the emissions increase cited above. This mechanism includes various combinations of small refiner diesel volume reduction, aromatics content reduction, cetane number increases, and additive concentration increases.

Because Kern Oil and Refining Company (Kern) is the only small refiner currently qualifying for the small refiner provisions of the Phase 3 RFG regulations, the analysis in this section will be specific to Kern. Kern is interested in producing 8,000 barrels per day of gasoline to the small refiner RFG standards. This means that Kern is required to offset 164.8 pounds per day of exhaust THC (8,000 x 0.0206), 257.6 pounds per day of NOx (8,000 x 0.0322), and 84.0 pounds per day of benzene-equivalent PWT (8,000 x 0.0105).

The proposed regulations provide three different options for offsetting the excess emissions arising from compliance with the small refiner provisions of the Phase 3 gasoline regulations. These are:

1) An increase in the amount of diesel produced to the 20 percent aromatics standard, accompanied with a reduction in aromatic content, an increase in cetane, and an increase in additive concentration.
2) Retention of the existing diesel volume of diesel produced to the 20 percent aromatics standard, accompanied with reduction in the aromatics content, increases in the cetane number, and an increase in additive concentration.
3) A reduction in the volume of diesel produced to the 20 percent aromatics content specification of the diesel aromatics content regulation.

The emissions reductions resulting from diesel aromatics reduction and cetane increases are calculated by multiplying the diesel fuel emissions factors (in units of pounds per barrel), by the volume of diesel fuel produced, and then multiplying this product by the percent change in emissions resulting from the aromatics and cetane changes. The percent changes in emissions are calculated from regression equations which have been developed from test programs designed to investigate the effects of changing diesel fuel properties on emissions.

Methodology

Kern may consider an option to increase its diesel production by about 25 percent from its 6,405 barrel per day limit of 20 percent-equivalent alternative diesel it is allowed to produce under the small refiner provisions of Section 2282, to 8,000 barrels per day. If Kern does this, it would mean that, for 1,595 (8,000-6,405) barrels per day, the difference in emissions between a 10 percent-equivalent alternative diesel formulation and a 20 percent-equivalent alternative formulation would have to be offset by Kern. This additional excess emissions can be calculated using the diesel emissions factors (in pounds per barrel), and the incremental diesel production (1,595 barrels per day). The applicable diesel NOx emissions factors are as follows: Diesel fuel with 10 percent aromatics (or 10 percent-equivalent alternative formulations) NOx emissions are 4.719 pounds per barrel. For small refiner diesel fuel produced to the 20 percent aromatics standard (or 20 percent-equivalent alternative formulations) NOx emissions are 4.879 pounds per barrel. The applicable PM emissions factors are: 0.205 pounds per barrel for 10 percent-equivalent formulations, and 0.236 for 20 percent-equivalent formulations. The applicable THC emissions factors are: 0.462 pounds per barrel for 10 percent-equivalent formulations, and 0.499 pounds per barrel for 20 percent-equivalent formulations.

The additional excess emissions from the 1,595 barrel per day increased diesel production that would have to be offset are: NOx: 255.2 pounds per day (1,595 x (4.879-4.719)), and PM: 49.4 pounds per day (1,595 x (0.236-0.205)). There are no increased THC emissions to be offset from the increased diesel production because the diesel aromatics regulation was not adopted as a THC emission reduction measure. The table below summarizes the total offsets required from the diesel fuel that will be produced by Kern Refining Company. The first line in the table is for the case where Kern does not increase its diesel production above its current 6,405 barrel per day 20 percent-equivalent cap (that is, only the excess emissions from 8,000 bpd of gasoline would have to be offset). The last row in the table shows the offsets that would be required if Kern elects to increase its diesel fuel production to 8,000 barrels per day.

Summary of Excess Emissions for Kern Oil

Source	THC (lb/day)	NOx (lb/day)	PM (lb/day)
Small Refiner Gasoline (8,000 BPD)	164.8	257.6	84.0/10.3=8.2
Increase Diesel Production (1,595 BPD)	0	255.2	49.4
Total	164.8	512.8	57.6

In the above table, the value of the required PM offsets for the small refiner gasoline was divided by 10.3. This reflects the fact that PM emissions from diesel fuel are 10.3 times more toxic than benzene emissions (potency of 3.00×10^{-4} vs. 2.90×10^{-5}). Thus, the PM reductions are put on the basis of pounds of PM from diesel.

The regressions shown below were used to estimate the emissions reductions that would result from changing the cetane number and aromatics content of the diesel fuel produced by Kern. The regressions resulted from testing conducted by the Southwest

Research Institute in 1990 and summarized in the report "Study of Fuel Cetane Number and Aromatic Content Effects on Regulated Emissions from a Heavy-Duty Diesel Engine."

lnTHC (g/hp-hr) = 1.015 - 0.9539*(ln(cetane-35))
lnNOx (g/hp-hr) = 1.587 + 0.00296*FIA aromatics - 0.04276*(ln(cetane-35))
lnPM(g/hp-hr) = -1.439 + 0.003617*FIA aromatics - 0.1734*(ln(cetane-35))

Using these regressions, percent emissions reductions were calculated for various levels of aromatics content and cetane number. The baseline fuel properties for these calculations were the properties of Kern's current 20 percent aromatics-equivalent alternative diesel formulation. The percent emissions changes predicted by the regressions were multiplied by Kern's anticipated diesel production and the baseline emissions factors to give the estimated reduction in emissions (on a pound per day basis) that would be available to offset the estimated excess emissions shown in the table above. The calculations were done for both diesel production volume scenarios of 6,405 barrels per day and 8,000 barrels per day. The baseline emissions factors that were used are shown below.

Baseline Emissions Factors
THC: 0.462 lbs/bbl
NOx: 4.879 lbs/bbl
PM: 0.236 lb/bbl

In addition to increases in cetane number and decreases in the aromatic content, Kern also proposed to increase the amount of the additive that it uses in diesel fuel. The additive has been shown to decrease both NOx and PM emissions. Kern proposed that the concentration of the additive in the diesel fuel be increased by 0.02 volume percent. The additive decreases NOx emissions by about 0.3 percent per 0.01 volume percent of additive, and PM emissions by about 0.565 percent per 0.01 volume percent of additive.

Using the regressions, emissions reductions estimation method, and values for the additive effectiveness shown above, the staff computed the emissions reductions that would be available to offset the excess emissions arising from the 8,000 barrels per day of gasoline produced to the small refiner standards, and to offset the emissions increase resulting from the increase in diesel production from 6,405 barrels per day to 8,000 barrels per day (for the 8,000 barrel per day diesel production scenario).

Kern may also consider a reduction in the production volume of its 20 percent-equivalent alternative diesel formulation as a means of offsetting the excess emissions from the small refiner gasoline (option 3). As with option 1, the available offsets for this option were calculated using the difference between the 20 percent-equivalent formulation emissions factors and the 10 percent-equivalent formulation emissions factors. These differences are: for NOx: 0.16 pounds per barrel (i.e., 4.879-4.719), for PM: 0.031 pounds per barrel (i.e., 0.236-0.205), and for THC: 0.037 pounds per barrel (i.e., 0.499-0.462). The pounds per day excess emission values shown in line one (Small Refiner Gasoline) of the above table were divided by these emission factor differences to estimate the reduction in diesel volume needed to provide the necessary offsets. In the case of THC, it was also assumed that 29.5 percent of the PM reductions that are achieved could be used as THC offsets. The rationale for this is that approximately 29.5 percent of PM emissions are the soluble organic fraction (SOF), which is emitted from the engine as gaseous hydrocarbons.

Results

For the 8,000 barrel per day diesel production scenario, the aromatics content of Kern's diesel fuel would have to be reduced by 3.5 percentage points, and the cetane number would have to be increased by 0.5 number in order to provide the emissions reduction necessary to offset the excess emissions arising from the gasoline produced to the small refiner specifications, and to offset the increased emissions from the additional 1,495 barrels per day of diesel production. For the 8,000 barrel per day diesel case, Kern would have to increase the additive concentration of its diesel fuel by 0.02 volume percent. For both the 6,405 barrels per day and the 8,000 barrels per day diesel production cases, no changes to the sulfur content, nitrogen content, and poly-cyclic aromatic (PAH) content of Kern's diesel fuel would be required.

For the 6,405 barrel per day diesel production scenario, using the same basic calculations as above the staff's analysis shows that the aromatics content of Kern's diesel would have to be reduced by 2.0 percentage points and the cetane number would have to be increased by 0.5 number in order to provide the emissions reductions necessary to offset the excess emissions arising from the gasoline produced to the small refiner specifications of the Phase 3 regulations.

For the reduced production of Kern's 20% equivalent diesel fuel, to mitigate the expected increase in emissions associated with the small refiner provision of the CaRFG3 regulations, Kern would have to decrease its production to 2263 barrels per day.

References

1. Investigation of the Effects of Fuel Composition and Injection and Combustion System Type on Heavy-Duty Diesel Exhaust Emissions, Terry L. Ullman, Southwest Research Institute, under contract to the Coordinating Research Council, Inc., March, 1989.
2. Study of Fuel Cetane Number and Aromatic Content Effects on Regulated Emissions from a Heavy-Duty Diesel Engine, Terry L. Ullman, et. al., Southwest Research Institute, under contract to the Coordinating Research Council, Inc., September, 1990.