**Comparison of Two Methods for Measuring Octane Rating[[1]](#footnote-1)**

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**Objective**

Two methods[[2]](#endnote-1) for determining the octane ratings of blends of gasoline are found in the standard operating procedures for the plant: (1) the motor method and (2) the research method. Proposed improvements in the control system of the reforming and isomerization units require highly consistent measurements of octane ratings. This memo outlines experiments performed to assess the agreement between the two methods.

**Experimental Apparatus and Procedure**

Two 100 hp calibrated engines were used to conduct the octane rating tests. The motor method used a 900 rpm motor with preheated fuel, while the research method used a standardized engine at 600 rpm. At a certain load, the engine will knock, resulting in a pinging noise from ignition of the fuel at more than one location. The amount of knock is measured using a “Knock meter,” which measures the magnitude of vibration in the piston due to knock. Figure 1 shows a photo of the 600 rpm motor used in this experiment.



**Figure 1. Photo of the CFR ASTM test engine used to measure octane rating.**

The procedure is to run three fuels through the engine. A calibrated fuel with known octane rating is run in the engine and the pressure ratio is changed to obtain maximum knock. The air-to-fuel ratio is then changed at that pressure ratio until a maximum is observed in the knock meter. A second calibrated fuel is then run at the same pressure ratio that gave maximum knock for the first fuel, and the air-to-fuel ratio is again changed to obtain maximum knock. Finally the fuel of interest is run at the same pressure ratio as fuel 2, changing the air-to-fuel ratio to obtain maximum knock. The knock meter reading from the fuel of interest is a linear combination of the knock readings from the two calibrated fuels, and is then used to interpolate the octane rating for the fuel of interest.

**Theory**

The ratio of the knock meter readings must be equal to the ratio of the octane ratings. If the first calibrated fuel has an octane rating of 87 and the second calibrated fuel has an octane rating of 85, the knock rating (OR3) of the desired fuel can be determined from the knock meter readings (KMR) in the engine, as follows:

 $\frac{OR\_{3}-OR\_{2}}{OR\_{1}-OR\_{2}}=\frac{OR\_{3}-85}{87-85}=\frac{KMR\_{3}-KMR\_{2}}{KMR\_{1}-KMR\_{2}} $ (1)

where the subscript “3” refers to the fuel of interest.

**Experimental Method**

Thirty-two blends of gasoline ($n$ = 32) were created by combining 2 gallons of normal pentane (62 octane) with varying amounts of toluene (120 octane) to create test samples with octanes in the range 80 – 110. After thorough mixing, each blend was separated into two samples of equal volume. The octane of one sample was measured using Method #1 and the other using Method #2.

To determine if the two methods give the same octane rating given the same gasoline blend, the results were analyzed using a paired *t­*-test.[[3]](#endnote-2) This test was performed by defining the $i^{th}$ difference as $d\_{i}=y\_{1,i}-y\_{2,i}$ where $y\_{1,i}$ and $y\_{2,i}$ are the octane ratings given by the first and second methods respectively for the $i^{th}$ sample. The hypothesis $δ$ = 0, where $δ$ is the true mean difference between the two methods, was tested at the 95% confidence level ($α$ = 0.05).

**Results and Analysis**

The results of 32 tests are shown in Figure 2 on a parity plot (i.e., octane rating of Method #2 vs. octane rating of Method #1). Each blend appears as one point on the graph. The data points do not lie on the parity line. In each case, Method #2 produces higher octane rating than Method #1. The amount of disparity is not correlated with octane value since similar differences between the two methods are found at both high and low ratings.

Figure 2. Comparison of octane measurements using the motor (Method #1) and research (Method #2) methods.

The statistical analysis of the results requires the calculation of the difference in the octane values produced using the two methods for each sample. These data are found in Table 1 along with the exact octane ratings obtained using each method for the 32 blends of gasoline tested. The data are presented in order of ascending octane values, but the samples were created and tested in a random manner as indicated by the first column in Table 1.

Table 1. Differences in the octane values obtained using both the motor and research methods for 32 Samples

|  |  |  |  |
| --- | --- | --- | --- |
| Sample | Method 1 | Method 2 | Difference |
| 2 | 81.4 | 83.3 | -1.9 |
| 31 | 82.2 | 93.5 | -11.3 |
| 12 | 83.1 | 89.2 | -6.1 |
| 16 | 83.8 | 85.9 | -2.1 |
| 4 | 84 | 94.7 | -10.7 |
| 15 | 84.7 | 88.8 | -4.1 |
| 21 | 84.8 | 95.3 | -10.5 |
| 29 | 85 | 92.8 | -7.8 |
| 20 | 85.9 | 97 | -11.1 |
| 13 | 86.2 | 93.6 | -7.4 |
| 11 | 86.5 | 92.3 | -5.8 |
| 17 | 86.8 | 96.5 | -9.7 |
| 32 | 87.4 | 97.5 | -10.1 |
| 14 | 87.7 | 97.4 | -9.7 |
| 24 | 87.7 | 93.9 | -6.2 |
| 30 | 87.9 | 95.7 | -7.8 |
| 5 | 88.1 | 99.7 | -11.6 |
| 22 | 89.3 | 100.2 | -10.9 |
| 28 | 90 | 99.1 | -9.1 |
| 8 | 90.2 | 98.6 | -8.4 |
| 18 | 90.2 | 99.5 | -9.3 |
| 26 | 90.7 | 98.4 | -7.7 |
| 25 | 91.3 | 97.4 | -6.1 |
| 3 | 91.4 | 99.4 | -8 |
| 6 | 91.4 | 94.1 | -2.7 |
| 23 | 91.7 | 96.3 | -4.6 |
| 19 | 92.4 | 99.8 | -7.4 |
| 27 | 93.7 | 101.3 | -7.6 |
| 9 | 94.7 | 103.1 | -8.4 |
| 7 | 98 | 101.9 | -3.9 |
| 1 | 105 | 106.6 | -1.6 |
| 10 | 105.5 | 106.2 | -0.7 |

The average difference is -7.1 and the standard deviation of the difference is 3.0. Differences are not dependent upon the magnitude of the octane value since both large and small differences are found throughout the entire range of octanes. The test statistic for the average difference being equal to 0, with 31 degrees of freedom, is -13.2. At the 95% confidence level, the two-tail t-statistic for 31 degrees of freedom is 2.040. Since |-13.2| > 2.040, there is sufficient evidence to conclude that the two methods for calculating the octane rating of a sample of gasoline do not produce the same results. The 95% confidence interval for the difference indicates that Method #2 generates ratings between 6.0 and 8.2 octane units higher than Method #1.

A literature search showed that the motor research method commonly gives octane readings 8 to 9 units higher than the motor method. Further research showed that most industrial companies average the two readings and then post a notice saying that the octane is the average of the two methods, such as:

 $Octane Rating=\frac{R+M}{2}$ (2)

Therefore, the differences between the two ratings observed in Figure 2 agree with findings in the literature.

**Conclusions/Recommendations**

The data indicate that the two methods currently used in the plant to calculate the octane rating of gasoline blends do not produce similar results. The motor research method (Method #1) yields octane readings that are between 6.0 and 8.2 units higher than the motor method (Method #2). Since the proposed control system requires consistent measurements of octane rating, selecting one method to use throughout the plant is desirable. This study did not address the accuracy of each method, nor other factors such as the cost, reliability, or equipment issues. A literature search showed that the motor research method commonly gives octane readings 8 to 9 units higher than the motor method, and that industry averages the two readings. It is therefore recommended that both tests be performed on each sample and that the average of the two readings should be reported.

1. This is a sample report for the UO Lab and illustrates types of sections needed for a complete report. The data and conclusions are not necessarily real. [↑](#footnote-ref-1)
2. R. D. Snee, Developing blending models for gasoline and other mixtures, *Technometrics*, **23**, 119-130 (1981). [↑](#endnote-ref-1)
3. This report was prepared for pedagogical purposes. The data and data analysis were taken from an example in Chapter 4 of *Statistical Methods for Engineers* by G. Geoffrey Vining. [↑](#endnote-ref-2)