Portable Near-Infrared Octane Analyzer
Use by State Agencies for
Checking Compliance at the Service Station Level

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PRESENTED AT THE
NINTH INTERNATIONAL CONFERENCE
ON NIR SPECTROSCOPY
VERONA ITALY
JUNE 1999

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INTRODUCTION

Since the first gasoline pumps were installed, there have been ways to increase profits by “misinforming the customer.” To help stem this problem, the United States adopted a “weights and measures” program that requires states to monitor the volume of gasoline being dispensed by the gasoline pump.

As years went on, additional tests have been added at the service station level to check not only the quantity, but also the quality of the gasoline sold to the consumer. This paper describes one of the newest tools being utilized for verification at the service station level – portable octane analyzers. These instruments allow screening of octane level to help control the quality of petroleum products sold to consumers.

BACKGROUND

In a broadcast by DATELINE NBC in July 1993[1] it was reported that 22 states, almost half of the states in the United States, do not have any kind of gasoline quality testing program. Almost all states in the United States follow NIST Handbook 44, Section 3.30[2] for volume testing of gasoline pumps and validation of money value, but these tests do not help determine the quality of gasoline.

State level gasoline quality testing programs were started in some states as early as the 1960s to control the octane and other properties of gasoline for consumer protection. Until recently, octane analysis had been done only by conventional Waukesha CFR engine which is time-consuming, expensive and slow. CFR engine testing made enforcement difficult because of the time lag between pulling the sample and analysis, which is typically days. Currently, over half of the states in the United States are using near-infrared analyzers to measure the octane in gasoline at the service station level. These tests are used to determine whether the samples need the expensive and time consuming CFR engine test.

Each state sets up its own protocol for testing with Near-IR, but all of them include comparison testing versus CFR results. (Figures 1 & 2)

Summary of Validation Studies .

Test Site	Test Type	Standard Error of Estimate	Correlation
Maryland	RON	0.55	0.97

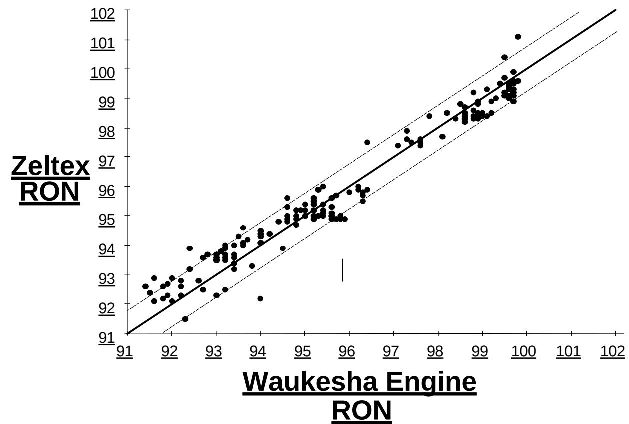

FIGURE 1

Summary of Validation Studies .

Test Site	Test Type	Standard Error of Estimate	Correlation
Maryland	MON	0.59	0.95

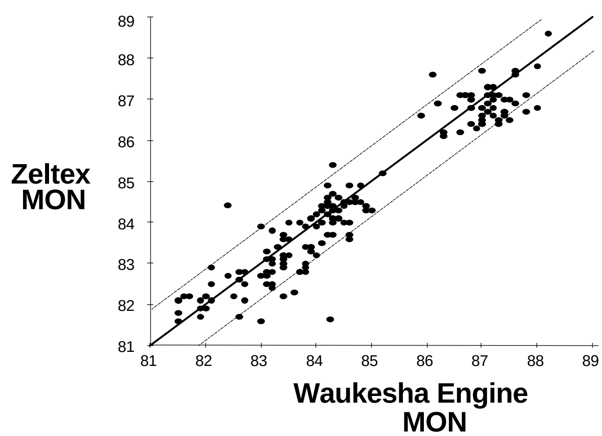

FIGURE 2

This paper includes data from state labs comparing Near-IR analyzers versus CFR engines to demonstrate that low-cost, portable instrumentation is a benefit and cost savings to enforcement agencies.

ASTM 2699/2700

Enforcement testing of octane in gasoline is required to be done as defined by American Standard Testing Methods (ASTM 2699, 2770)[3]. These protocols state that the Waukesha CFR engines are to be used to accomplish the official lab test. The standard errors as defined by ASTM are given in Table 1[4]. As you will note, they are given for a specific value of gasoline. Reproducibility and repeatability varies with differences in the octane number.

ASTM Specifications for CFR Engine Testing				
	As per Procedure	**Reproducibility** (95% confidence)	**Repeatability** (95% confidence)	**Octane Number**
RON	2699	± 0.7	± 0.2	95
MON	2700	± 0.9	± 0.3	85

Table 1

TECHNOLOGY

In 1993, Zeltex, Inc. developed the technology for a portable near-infrared octane analyzer to control the quality of gasoline in the field and at the refinery level. The result of this development is the ZX101C Portable Octane Analyzer. Zeltex uses patented source array technology (Figure 3)[5] to allow the ZX101C to produce a spectrum of 14 wavelengths without any moving parts in the optics or sampling system. The totally solid-state optical system allows lower power consumption, therefore, battery operated portability became realistic. The ZX101C uses infrared emitting diodes and narrow band filters ranging from 893 nanometers to 1045 nanometers.

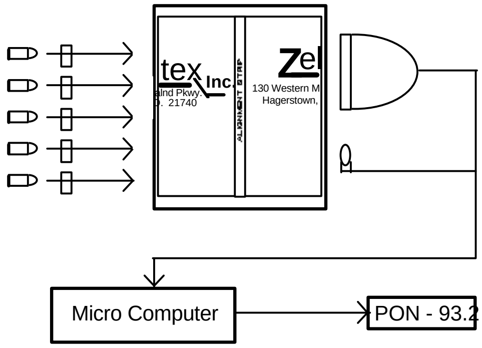

Figure 1
Schematic Diagram of ZX101C Optical System

FIGURE 3

ORIGINAL RESEARCH

The original research was conducted in 1993 with the help of the State of Maryland Motor Fuel Testing Lab. The Maryland Motor Fuel Testing Lab has supplied Zeltex with samples collected throughout the state of Maryland over the last 5 years. This wide collection of samples allowed for seasonal variations in Read Vapor Pressure, MTBE, TAME, and other additives to be included in the calibration (Table 2)[6].

	RVP	MTBE	TAME	ETBE	DIST-10	DIST-EP
Hi	15.0	17.4	11.9	11.3	67	317
Low	6.5	0	0	0	35	176

TABLE 2

Maryland has an aggressive consumer protection gasoline-testing program that is divided into two sections:

1. Weights and Measures is empowered to check the quantity of fuel delivered at all service stations and marinas in the state of Maryland to assure they are in accordance with Handbook 44, Section 3.30

2. The Motor Fuel Test Lab checks the quality of the gasoline. This program started in 1970 and the Motor Fuel Test Lab was opened in 1974 to help assure Maryland citizens are receiving the quality of gasoline they are purchasing. This program has been successful in assuring that the quality of gasoline is correct in Maryland in over 97% of all samples tested. Other states without an aggressive program have not done as well (Figure 4).

Summary of validation studies

Test site	Test Type	Standard error of estimate	Correlation
Maryland	(R+M)/2	0.46	0.98

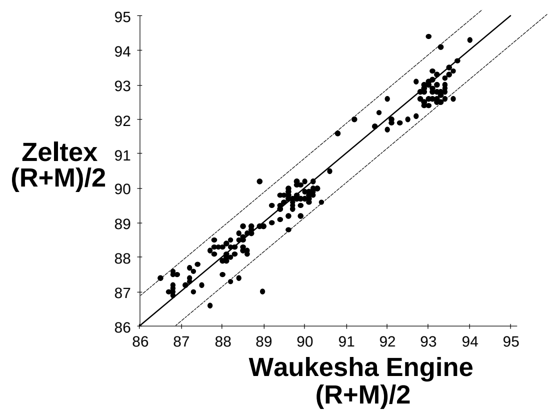

FIGURE 4

DATELINE NBC[7] discovered that in one state where there was no gasoline testing, over one-third of the people who purchased gasoline were not getting the octane for which they paid. DATELINE NBC[8] also discovered a very simple octane-cheating program that was going on in Indianapolis in 1993 where, at one station, the high test and regular pumps were pulling gasoline from the same tank. This problem was also discovered in West Virginia with the help of a ZX101C at the service station.

All these problems in 1993 led to a surge of petroleum quality testing by State labs in the United States. Many states, like West Virginia, took a very aggressive approach to consumer complaints of service station gasoline quality. State inspectors have a large number of tools available to field test service station gasoline. These field tests include water bottom test, VDus water test and now octane testing. West Virginia pre-screens octane samples using the ZX101C, identifying which samples are most likely to be non-conforming before sending selected samples to be tested on CFR engines.

Other states, such as Virginia, use a Near-IR analyzer to pre-screen samples at the knock engine itself. To get an accurate reading from CFR engines, you must know the approximate octane number of the gasoline prior to testing. If your estimate of the value of the octane number on the test sample is not between the bracketed reference fuels (normally ±2 O.N.), you need to rerun the sample an additional time to get it to the correct octane value. This repetitive testing is costly ($80 to $150 per sample) and time consuming where pre-screening allows setting of the CFR engine correctly each time.

Method	Number of samples	No. of samples failing octane ASTM req't	Sample number of failed samples
CFR Engine	166	2	1409, 1517
ZX101C	166	2	1409,1517

Non-Compliance Uses For A Portable Octane Analyzer

Some state labs have found other uses for portable octane analyzers in the field besides detecting inappropriate octane content being sold to the consumer. West

Virginia has used octane analyzers to help a service station owner and the EPA correct an unintentional problem without causing the service station irreparable harm.

Summary of validation studies

Test Site	Test Type	Standard Error of Estimate	Correlation
Virginia	(R+M)/2	0.49	0.98

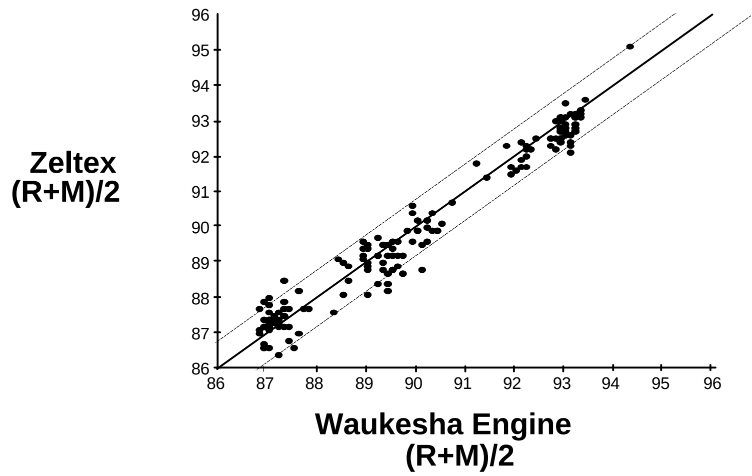

FIGURE 5

In West Virginia, the Department of Environment Protection (DEP) was notified by a service station that fuel was found within a monitoring well at the service station. Since this service station was located next to a major creek, the environmental impact could have been devastating to the local ecology if the leak was not corrected quickly. The DEP team confirmed there was indeed fuel in the monitoring well. They told the gas station to drain all three underground tanks so they could determine which of the three underground tanks had the leak. This would be extremely expensive, time consuming and damaging to the service station since they would need to close the service station, bring in tankers, pump out the fuel, hire someone to go into all three tanks or dig up all the tanks to fix this problem.

Before closing the service station, the DEP contacted West Virginia's Division of Labor – Weights and Measures for assistance in detecting which tank was leaking. Mr.

Dennis Harrison responded to the DEP's request. One instrument Mr. Harrison took with him was a ZX101C Portable Octane Analyzer. Mr. Harrison proceeded to test the 87, 89 and 93 octane fuels at the nozzle to help determine which tank was leaking. Upon testing, the monitoring well exhibited a value of 88.9 (R+M)/2. This reading is not an exact value of any of the fuels tested, but it was extremely close to mid range, (89.6) and the RON was the same (Table 3). Since the fuel in the monitoring well passed through earth, the contamination lowered the octane level. The station proceeded to pump the 89 octane gasoline into the 87 underground tank. This way the DEP was able to stop environmental damage, keep the station open to sell 93 and 87 octane fuel, and confirm which tank needed to be fixed.

AT PUMP:	87	89	93	MONITORING WELL
RON	92.7	94.5	97.9	94.5
MON	82.3	84.7	87.7	83.3
(R+M)/2	87.5	89.6	92.8	88.9

TABLE 3

Another use for the Portable Octane Analyzer by State Inspectors is determining the accuracy of blending pumps.

A phenomenon that is becoming standard in the United States is blending pumps. Blending pumps have eliminated the need for a third underground tank. With blending pumps, a service station only needs two storage tanks, one at 87 octane and one at 93 octane. A blending pump mixes the two octane values to give the mid-grade gasoline. This has been a boon for the service station industry reducing the start-up cost and inventory cost.

Blending pumps are calibrated to dispense a set percentage from each tank to make the blended fuel's octane level correct. Unfortunately, blending pumps go out of calibration. The current test for a service station is to have a single sample chosen from one blending pump to determine if all the pumps were dispensing correctly. This method works poorly on large service stations that have a large number of pumps. Many states now use the ZX101C to test each blending pump at a service station to see if the blend is correct.

The repeatability of the ZX101C (Table 5)[9] allows a quick assessment to determine if all the pumps are blending correctly. This is a test where the absolute values from CFR engines are not needed to evaluate whether the pump is blending the correct volume from each tank.

TABLE 5

Precision study: 25 retests by a single user

	RON	**MON**	**(R+M)/2**
Mean Value	98.4	87.9	93.2
95% confidence	±0.25	±0.12	±0.12
Maximum reading	98.6	88.1	93.3
Minimum reading	98.2	87.8	93.1

TABLE 6

Precision study: 25 retests (5 by each of 5 users)

	RON	**MON**	**(R+M)/2**
Mean Value	98.4	87.9	93.2
95% confidence	±0.25	±0.12	±0.10
Maximum reading	98.7	88.1	93.3
Minimum reading	98.1	87.8	93.1

CONCLUSIONS

The use of a portable near-infrared octane analyzer has allowed state and other governing agencies such as Russian State Committee for Standards of USSR, (Russian Goststandart), and the National Bureau of Technology Supervising in China, to regulate the quality of gasoline without the necessary delay and expense that are involved with CFR engine analysis.

The data from the state agencies shows that portable near-infrared octane analysis is extremely repeatable and accurate on unleaded gasoline. Therefore, the near-infrared portable octane analyzer should be used as a screening tool to allow states to protect the consumer and regulate the petroleum industry.

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