

will titrate weak bases and weakly basic degradation products in the sample that cannot have protective value. It is for this reason that our infrared TBN values are correlated to ASTM D4739.

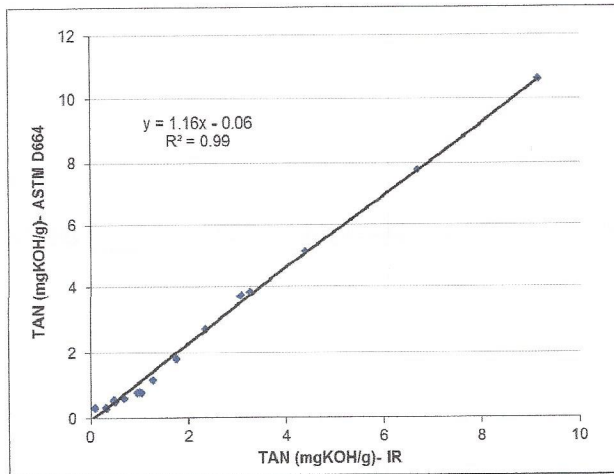


Figure 3: Relationship between ASTM D664 and infrared TAN values

The repeatability and reproducibility of these standard methods for used oils are well-documented. Repeatability is the variability of measurements on the same sample by the same operator using the same measurement equipment. Reproducibility is the comparison of independent tests.

For an in-service sample with a TAN of 2.0mgKOH/g, the comparison of independent tests (reproducibility) can yield results between 1.12 and 2.88mgKOH/g, with repeatability between 1.77 and 2.23 mgKOH/g.

ASTM D664 REPRODUCIBILITY	ASTM D664 REPEATABILITY
$R = 0.44 * x$	$r = 0.117 * x$
Where x is the average of two separate TAN readings	

For comparison, the IR methods show typical TAN reproducibility relative to an ASTM titration measurement of 0.49 mgKOH/g at a 99% confidence interval in the normal operating range of TAN below 4 mgKOH/g. Thus for a nominal sample with 2 mgKOH/g, the results can be expected to range between 1.51 and 2.49 mgKOH/g, comparable to the ASTM method.

Repeatability is calculated at 6.8% RSD at the 99% confidence interval at the mid-range of the measurement window (0-10 mg-KOH/g), which is similar to the ASTM method.

A typical calibration curve for turbine oils is shown in Figure 3. The fig-

ure depicts several different brands and states of lubricant breakdown.

For an in-service sample with a TBN of 10 mgKOH/g, titration results can range from 5.5 to 14.5mgKOH/g within the specification, with repeatability between 9.6 and 10.4 mgKOH/g.

ASTM D4739 REPRODUCIBILITY	ASTM D4739 REPEATABILITY
$R = 1.54 * X^{0.47}$	$r = 0.22 * X^{0.47}$
Where X is the average of two separate TBN readings	

For TBN, both IR methods show typical reproducibility relative to an ASTM titration of 3 mgKOH/g at a 99% confidence interval over a range of 0-16 mgKOH/g. For a sample with a nominal TBN of 10 mg-KOH/g this implies one would encounter a range of results between 7 to 13 mgKOH/g, comparable to the ASTM method at this common level of TBN for new engine oils. Repeatability is 0.37% RSD at a 99% confidence interval, better than the ASTM D4739 method.

Figure 4 shows a calibration curve for reciprocating engine oils, based on a variety of different oil brands and states of degradation.

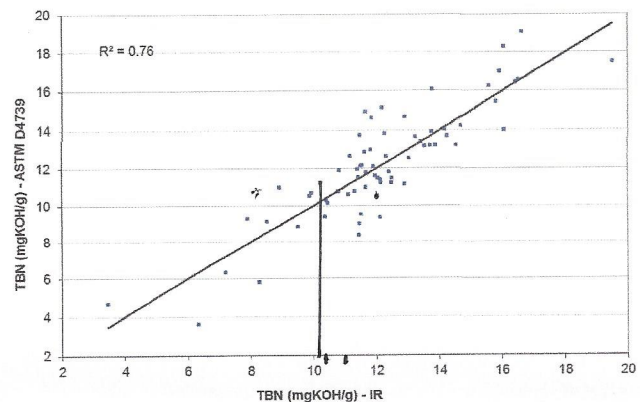


Figure 4: Relationship between ASTM D4739 and infrared TBN values. The usefulness of TAN and TBN measurements for monitoring oil degradation lies in consistent, frequent sampling and measurement. This practice produces many data points that show the trend in decrease in base reserve and increase in acidity over the lifetime of the oil. IR TAN and TBN measurements are quick and easy to perform and cost effective. Therefore, samples can be measured at short intervals and a close trend of the values can be followed effectively.

4. Example of TAN Correlation: Industrial Fluids

In order to illustrate the effectiveness of this direct infrared approach to providing TAN/ TBN values, we investigate the case of the "Industrial" fluid family. The lubricants in this family are a collection of transmission and hydraulic fluids as well as some gear oils. They all have base oils and additives that yield fluids with high shear stability and especially good low temperature flow properties. Despite