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ESTIMATION AND CORRELATION DEVELOPED FOR TOTAL BASE NUMBER (TBN) OF LUBRICATING OIL USING FOURIER TRANSFORM INFRARED SPECTROSCOPY

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ABSTRACT

Proper lubrication in the machine is very important. Without proper lubrication in the machine reduces the performance and life of machine. The working of machine in good condition depend on the quality of lubricants and condition of machine. The lubricating properties of lubricants decide the time interval of lubrication. Hence rather than the conventional way of changing the lubricant at the fixed interval, it is recommended that the oil be changed based on their lubricating properties.

Viscosity and Total Base Number (TBN) are two very important properties which affect the useful life of the oil.

Total Base Number (TBN) is measure of alkaline reserve present in the oil. TBN is defined as the amount of KOH required to balance HCl that in turn will balance all the basic components present in one gram of the lubricating oil. With time this basic component of the oil gets reduced, so it is a good parameter to assess the deterioration of oil.

Tom (2007) described how FTIR can be used for oil analysis and suggested the selection of correct parameters for specific applications. The present paper proposes to use Fourier Transform Infrared (FTIR) spectroscopy to find TBN value of the oil.

In this paper the trends in TBN with the transmittance of selected peak will be found out and the equations of the trend line will give the TBN value at any particular value of transmittance of FTIR spectra. So the proposed method will be more economical, simpler fast and compatible to be a part of online oil analysis system.

Keywords: *Total base number, Viscosity, FTIR, Lubricant andTransmittance.*

I. INTRODUCTION

Lubricants lose their properties with the use. Once the lubricants are stripped off their lubricating properties, they are drained off and new oil is poured in the machine. The time interval between pouring in of fresh oil and draining out the used oil is the useful life of the lubricant. Traditionally when the used oil will be poured out and fresh oil will be poured in is a fixed interval of time or fixed hours of running of the machine. This time interval is either decided by the oil supplier or by the original manufacturer of the equipment.

This should not be the recommended technique. The oil is subjected to different rate of deterioration for different conditions of the machines and also the working conditions into which the machine has been put. So the useful life of lubricant will be different conditions of machine and different work environment. There are two disadvantages of oil change at conventional fixed time interval-

- If the condition of machine is good and it is working in a good condition, there is always a possibility that the oil when it is being changed may be still having some useful life left with the lubricant. This results in loss of lubricant.
- If machine is old, not maintained properly and are working in a rugged environment, then the oil on being subjected to rough conditions, may lose its lubricating properties before the time interval decided for the oil change. This may result in under lubrication of the equipment. It is detrimental for the machine

Hence rather than the conventional way of changing the lubricant at the fixed interval, it is recommended that oil be changed based on their lubricating properties.

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The properties of oil at a pre-decided fixed interval be analyzed and when the properties fall down below a certain level then the oil will be changed.

Viscosity, Viscosity Index, Total Acid Number(TAN), Total Base number(TBN), flash point, pour point, water content, total undissolved contamination etc. are some of the properties of oil which may be used for this purpose.Total Base Number (TBN) is measure of alkaline reserve present in the oil. TBN is defined as the amount of KOH required to balance HCl that in turn will balance all the basic components present in one gram of the lubricating oil. During use the oil gets oxidized and forms many acidic compounds. These acidic compounds corrode the parts of equipment which are being lubricated. To protect the equipment from this acidic attack, the oil is provided with an alkaline reserve. These base compounds neutralize with the acidic compounds and protects the equipment from being attacked by acid. With time this basic component of the oil gets reduced, so it is a good parameter to assess the deterioration of oil.

Proposed method
The present study proposes to use Fourier Transform Infrared (FTIR) spectroscopy to find the TBN value of the oil.

A relationship between percentage transmittance vs wave number could be obtained from FTIR spectra. Based on the available literature prominent peaks would be selected and values of their percentage transmittance at different hours of running will be noted. The correlation between the percent transmittance and the hours of use would be calculated. The peak with highest correlation coefficient will be the main cause of oil deterioration. The trends in TBN with the transmittance of selected peak will be found out and the equations of the trend line will give the TBN value at any particular value of transmittance of FTIR spectra.

II. METHODOLOGY

Plan of the present work has been enumerated in the flow chart shown below:

Chronological selection of oil samples

↓

Finding TBN values of different oil samples

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To get the FTIR spectra of samples

↓

Correlation analysis and developing trend line equation.

Fourier transforms infrared spectrometer (FTIR)

Figure -1. Perkin Elmer-2000 FT-IR Spectrometer

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The FTIR Spectra of the oil samples were recorded on **Perkin Elmer FT-IR Spectrum 2000**, (Figure-10). In each case the oil sample without any treatment was spread between the slide of KBr (6 mm thick) and the reflectance spectrum was recorded. There are many other methods for FTIR Spectroscopy analysis, but in those methods the oil samples are processed / filtered before analysis. Spectrum reflectance method was applied because in this method pre-processing of oil sample is not required. Thus more accurate results are obtained indicating the state of oil at its operating condition. Percentage transmittance of the engine oil was measured using FTIR Spectrometer.

III. EXPERIMENTAL SET-UP

Total Base Number (TBN) is the measure of the alkalinity reserve of the petroleum products. It is defined as the amount of potassium hydroxide in milligrams necessary to neutralize the hydrochloric acid (HCl) which will be required to neutralize all basic constituents present in 1g of sample. 877 Titrino Plus titrator (Figure-2) was used to find The TBN of oil samples.

Chlorobenzene and acetic acid in 2:1 ratio by volume was used as solvent and $HClO_4$ in acetic acid as titrant. One gram of oil sample was measured and 75 ml of solvent was added to it. It was mixed on a magnetic stirrer. The electrode and burette tip of instrument was immersed in the solution. The titration was started and The TBN reading was provided by the instrument.

Figure -2. 877 Titrino Plus TBN Analyser

IV. RESULT AND DISCUSSION

Most of the literature on oil analysis was available on analysis of engine oil. The present work engine oil from a Dumper used in the open cast coal mine was collected. Details of the dumper and the engine oil are as follows-

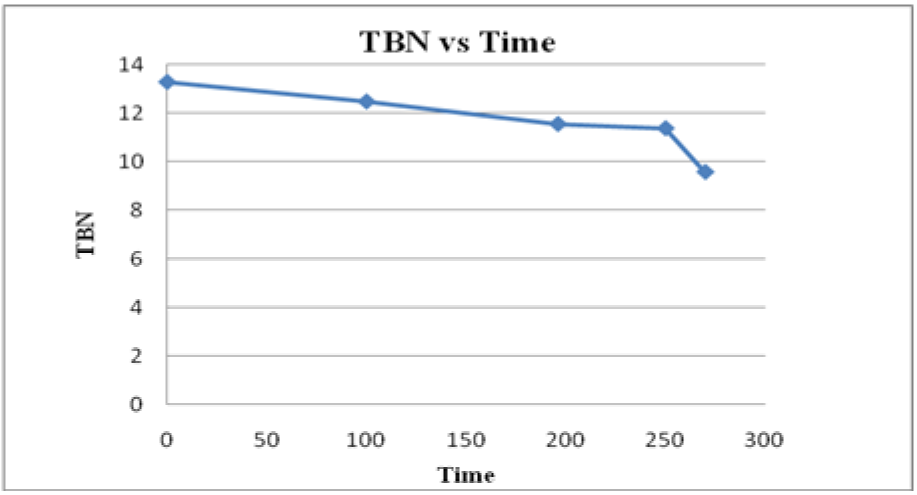
Engine make	:	Caterpillar
Capacity	:	100 Tonne
Type	:	Diesel, four stroke, turbo charged after cooled
Gross power	:	1000 HP
Net power	:	938 HP
Bore	:	17.02 cm
Engine oil Type	:	CH4 15W40
Engine oil make	:	Mak
Oil capacity	:	125 litres

Values of TBN for different samples have been shown in Table -1.

Table-1. TBN for different samples.

S. No.	Sample	Hours of running	TBN
1	Fresh	0	13.28
2	1	100	12.47
3	2	196	11.54
4	3	250	11.36
5	4	270	9.55

The TBN value of the oil against time has been plotted and shown in the graph-1.



Graph-1. Variation of TBN of the oil

TBN value of the engine oil decreases with time. Initially the decrease has been gradual and after 250 hrs. of running there is a rapid drop. The sudden drop is indication of some additive exhaustion.

V. FTIR

Fourier Transform Infrared (FTIR) spectrum of each of the oil samples have been given in, from graph-2 to graph-6. The superimposed spectrum of all the samples including fresh oil has been shown in graph-7.

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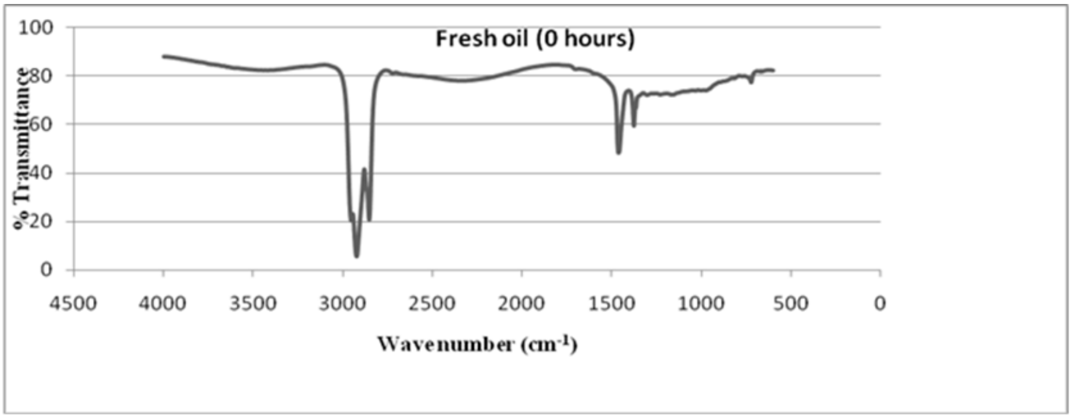
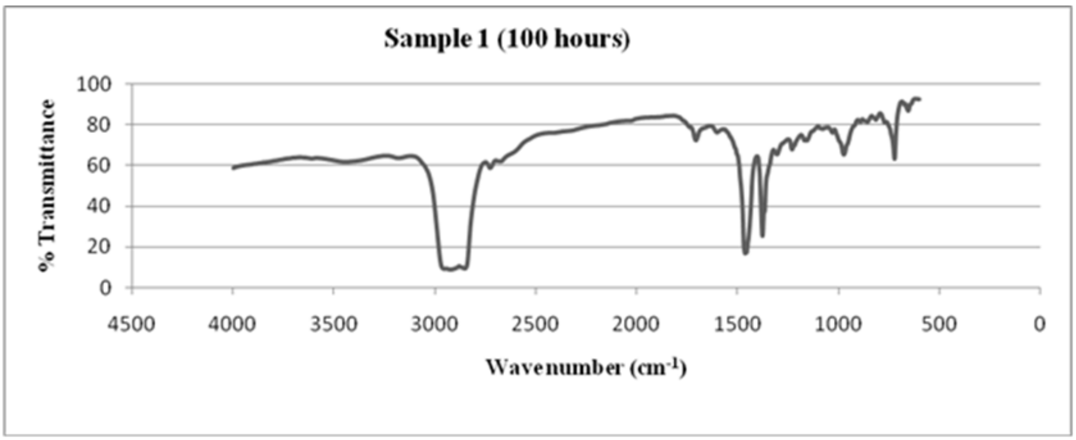
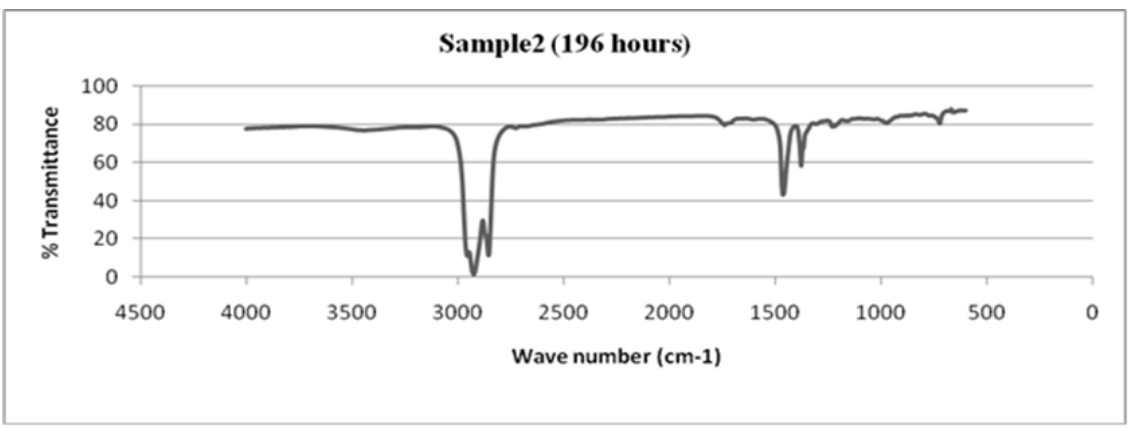


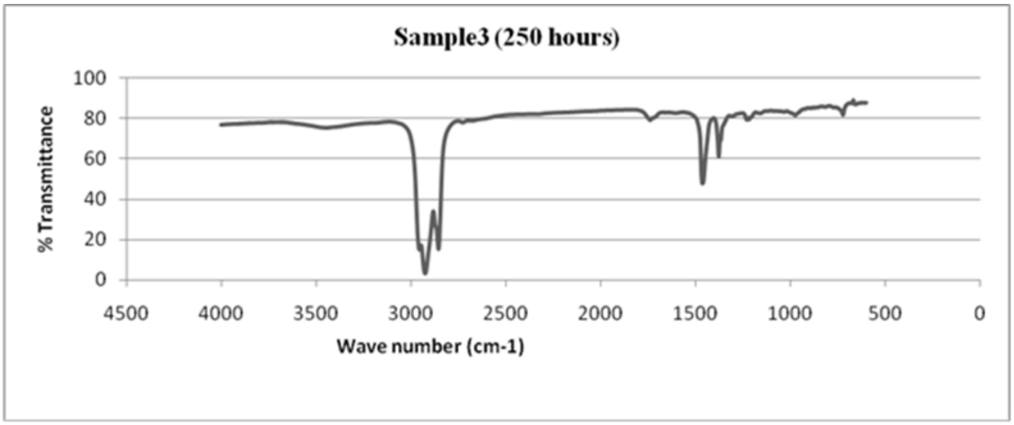
Graph 2. FTIR spectra of fresh oil



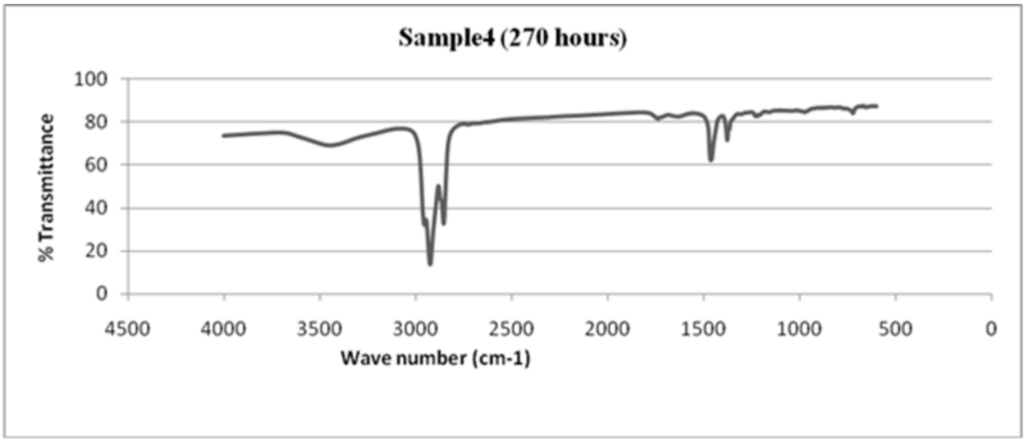
Graph 3. FTIR spectra of sample 1



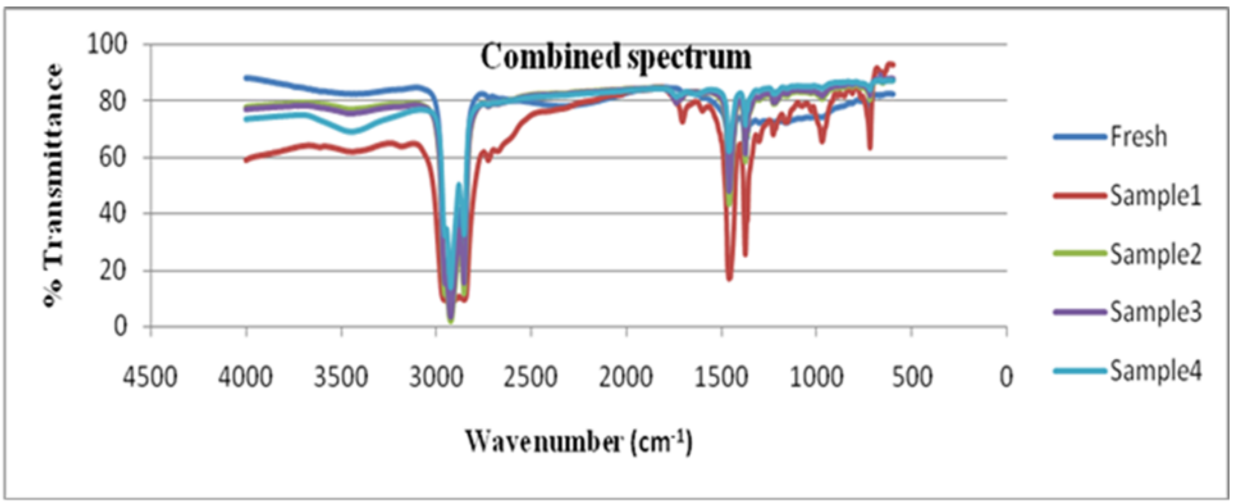
Graph 4. FTIR spectra of sample 2



Graph 5. FTIR spectra of sample 3



Graph 6. FTIR spectra of sample 4



Graph-7. Superimposed FTIR spectra of all samples

These sppectra are the relationship between percent transmittance vs wave number (cm^{-1}). The wave number of prominent peaks in the spectra were selected on the basis of available literature (Mukherjee et al., 2000; Kumar et al., 2005).Values of percentage transmittane at corresponding hours of running for these selected peaks were tabulated and have been shown in Table -2.

Table-2. Percent transmittance

Sl. No.	**Wave No.**	**Inference**	**Percent transmittance at different hours of running**				
			O hrs. Fresh	**100 hrs.** Sample1	**196 hrs.** Sample2	**250 hrs.** Sample3	**270 hrs.** Sample4
1	725	Sulphonic acid group	79.68	64.114	82.018	83.287	85.915
2	1379	S=O	61.778	26.922	59.839	62.576	73.319
3	1469	N=O and CH_2 bending	49.239	18.415	44.5	49.061	64.88
4	1620	Amides and nitro compounds	80.932	77.738	82.29	82.89	83.094
5	1750	Oxidation products, carbonyl region	84.167	74.53	80.928	80.327	82.14
6	2856	OH and CH_3 stretching	21.47	9.862	13.905	17.847	34.105
7	3500	Water	82.399	62.065	77.341	76.11	70.184

The values of TBN at different hours of running were taken from Table 1 and transmittance values from Table 2. The correlation coefficient of TBN with the peak values of the transmittance at different wave numbers were calculated using MS Excel. The values are given in the Table No. 3.

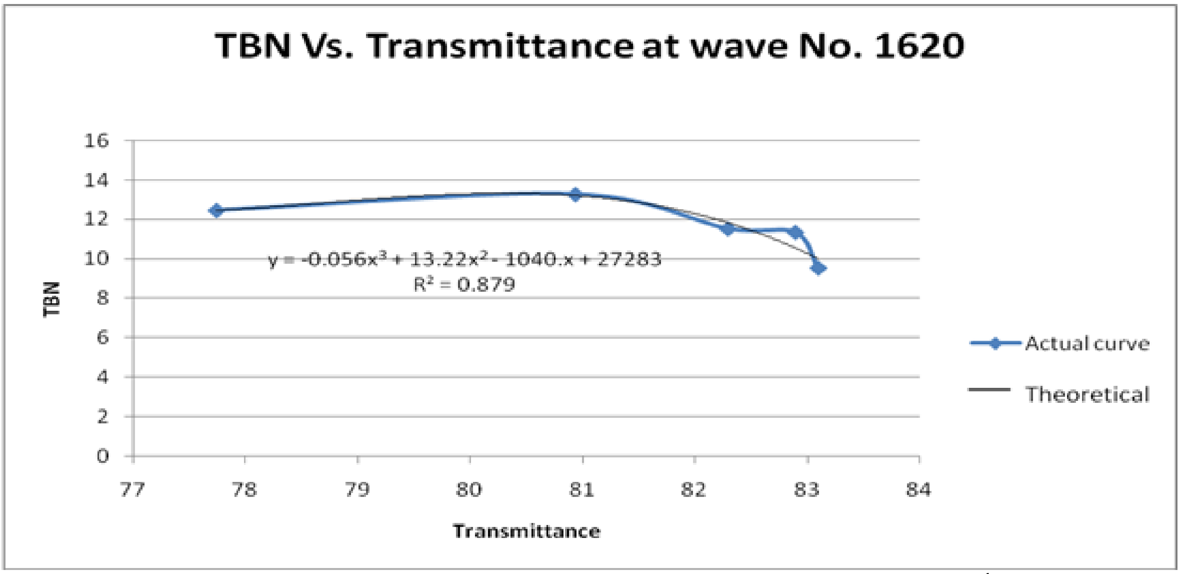
Table-3. Correlation coefficient with viscocity and TBN.

Sl. No.	**Wave No.**	**Inference**	**Correlation coefficient with TBN**
1	725	Sulphonic acid group	0.563
2	1379	S=O	0.54
3	1469	N=O and CH_2 bending	0.612
4	1620	Amides and nitro compounds	**0.714**
5	1750	Oxidation products, carbonyl region	0.117
6	2856	OH and CH_3 stretching	0.66
7	3500	Water	0.251

TBN value of the oil doesnot correlates well with the values of transmittance at corresponding hours of running. The correlation coefficient for most of the peaks is not high. The highest value of correlation coefficient is 0.714 at the wave number 1620 cm^{-1} indicating formation of Amides and nitro compounds. Nitration is another form of oxidation. Nitration results from the reaction of oil components with nitrogen oxides (NO_X) that are produced from the oxidation of atmospheric nitrogen during the combustion process. In addition to causing oil thickening nitration products are the major cause of the build-up of varnish or lacquers

It can be easily inferred from the above discussion that oxidation of the oil was the main reason behind oil deterioration.

From table 3, it is observed that changes in the TBN value of the oil can be best correlated with changes in percent transmittance of FTIR at wave number 1620 cm^{-1}.



Graph-8. Total base number (TBN) vs. Transmittance at wave number 1620 cm^{-1}

To investigate the above correlations, TBN of the oil has been plotted against the transmittance at 1620 cm^{-1}in the graph 8.

In graph 8, a best fit polynomial curve has been derived using MS excel.
If, x be the percent transmittance at wave number 1620 cm^{-1},
y be the TBN of the oil, then the TBN will be given by equation
$$y = -0.056x^3 + 13.22x^2 - 1040x + 27283$$

VI. CONCLUSION

Deterioration in the lubricating oil is reflected in the decrease in TBN value as reflected in FTIR spectrum.

The analysis of correlation of TBN with percent transmittance of FTIR spectrum suggested that TBN of the oil could be expressed in terms of transmittance value. The derived equation is

$$y = -0.056x^3 + 13.22x^2 - 1040x + 27283$$

Where x is the percent transmittance of FTIR spectrum at wave number 1620 cm^{-1}.

Determining TBN by conventional methods in the laboratory require a large amount of sample, are time consuming and costly. Using the suggested methods the TBN could be derived from the FTIR spectra itself. It requires very small amount of sample (a small droplet only) and gives result in seconds.

The above correlation study also suggested that oxidation of the oil was main reason for its deterioration. Correlation between percent transmittance of FTIR of seven prominent peaks and TBN values gave the highest correlation coefficient for oxidation and nitration of the oil..

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