

# Final Report

MBTC 2076

Physical and Chemical Characteristics of Superpave Binders  
Containing Air-Blown Asphalt from Two Different Feedstocks

by

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conducted by

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in cooperation with

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## Acknowledgements/Disclaimer

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## Abstract

Asphalt blends containing air-blown asphalt were compared with non air-blown asphalt blends from two different feedstocks. Data indicated one of the purported non air-blown asphalts was actually air blown, so a third feedstock was brought into the study. Inverse gas liquid chromatography, kinematic viscosity, refractive index, solubility, and diffuse reflectance Fourier Transform spectroscopy (DRIFT) were used to compare asphalt blends. Differences were observed between air-blown and non air-blown blends which led to predictions about relative polarities and a comparison between air-blown asphaltene aggregates and those of non air-blown asphaltenes. DRIFT data showed carbon-nitrogen, carbon-sulfur, and carbon-oxygen are oxidized in the air blowing process. The results may lead to three simple tests that can predict the presence of air-blown asphalt.

## Introduction

This project is a continuation of MBTC 2049 entitled “Physical and Chemical Characteristics of Superpave™ Binders Containing Air-Blown Asphalt”. In some situations, a producer may opt to produce a particular grade by blending a hard asphalt produced by the air blowing process with a soft asphalt. The properties of air-blown asphalt strongly depend on blowing conditions and starting material (1). Because the time to reach the desired consistency is greatly reduced by elevated temperature, there is an incentive to operate at high temperature. Air blowing temperatures can range from 230°C to 320°C. It has been shown that hardening and oxidation rates are higher for materials blown at higher temperature (1). In addition, a flux having a high saturate content, compared to one having a low saturate content when both are blown to the same high-temperature Performance Grade, generally will have a higher asphaltene concentration and a better Superpave™ PG span. However, these materials also have a higher hardening susceptibility, meaning that their physical properties deteriorate faster with subsequent aging (2). What makes this research important is that faster deterioration of physical properties of air blown asphalt with aging is not detected by Superpave™ specifications.

Asphalt aging is caused in part by its reaction with oxygen in the air. Air-blown asphalt has already reacted to some extent with air and, therefore, has been aged even before it is used on our highways. It is against the law in Arkansas for a producer to supply the state with air-blown asphalt. However, air-blown asphalt will meet grade specifications and will pass all physical testing in the same way as non air-blown asphalt. This makes the identification of air-blown asphalt difficult. One of the objectives of MBTC 2049 was to use the results of the study to find a test that would identify the presence of air-blown asphalt.

In MBTC 2049 it was determined that an air-blown asphalt blend aged faster than a blend of the same grade without air-blown asphalt. This test was conducted at atmospheric pressure and at a temperature of 80°C. Differences in air-blown blends and non air-blown blends were observed using Inverse Gas Liquid Chromatography. Air-blown blends showed higher phenol interaction coefficients (I<sub>g</sub>) and the I<sub>g</sub> values increased faster with oxidation in air at 130°C for air-blown blends. High I<sub>g</sub> values have been associated with poor road performance (3).

Using gel permeation chromatography, it was observed in MBTC 2049 that the average molecular weight of asphaltenes of air-blown blends was greater than that for non air-blown blends. This along with the IGLC work provided hope that tests could be developed to detect air-blown asphalt. This work focuses on air-blown blends from different feedstocks and will continue to look for chemical or physical tests that may be used to identify the presence of air-blown blends.

# Experimental

## Sample Preparation

Air-blown asphalts from companies A and B were prepared by blowing at 490-500F for 4.5 hours with an air rate of 1.11 gal/min. The air-blown material was blended with the base asphalt (for asphalt A this was a flux and for asphalt B this was a PG 52-28) to an ODSR at 67° C of 1.3 kPa. Based on experience from contacts in industry, both materials should pass PG67-22 specifications. The weight percent air-blown is 50% for blend A and 27% air-blown for blend B.

A third air-blown asphalt was studied in the project. The flux from Company C had a viscosity of 555 saybolt fural seconds, a softening point of 100° F, and a penetration value of 280/10 at 77° F. A hard asphalt with a softening point of 160°F and a penetration value of 7mm/10 at 77°F was prepared by propane extraction of the flux. Air-blown asphalt was prepared by air blowing the flux for 6.5 hours in a 1.59 gallon container at a temperature range of 490 to 500°F and an air flow rate of 1.1 ft<sup>3</sup>/min. The resulting air-blown asphalt had a softening point of 219°F and a penetration value at 77°F of 14mm/10. The flux from Company C was blended with 39 wt % air-blown asphalt to a PG64-22.

## Physical Testing

Physical testing and grading of the blends was done at the AHTD Material Laboratory in Little Rock, AR.

## Separation of Asphaltenes

Asphalt was mixed with heptane at a concentration of 10% (w/v). The mixture was refluxed for 2 hours and then left to settle 12 to 16 hours. The heptane insolubles were recovered on a Buchner funnel over an Erlenmeyer flask connected to an aspirator. The filtrate was washed on the filter paper three times with 50 mL portions of heptane and then placed in a beaker and stirred in excess heptane for 4 hours. The heptane insolubles were filtered again, washed three times with heptane, and then dissolved in toluene. The asphaltene toluene solution was stirred overnight and then filtered. Toluene was evaporated slowly in a hood leaving the purified asphaltenes.

### Flash Chromatography

The separation of asphalt into asphaltenes, resins, aromatics and saturates follows a method developed by Raki, et al (4). In this procedure, 50 mL of heptane were added to 5.0 grams of asphalt and the mixture refluxed for two hours. The mixture was cooled and filtered to obtain asphaltenes. 60 g of silica gel (15-40 $\mu$ m) were placed in a column connected to an aspirator and wetted with heptane. Maltenes were poured onto the silica gel and 100 mL of heptane were poured onto the silica gel. Saturates dissolved into heptane and were separated from the resins and aromatics using suction filtration. 100 mL of toluene were added to separate the aromatics from the resins and then 150 mL of tetrahydrofuran was used to dissolve the resins. Solvents were evaporated in a hood at room temperature

### Viscosity

Viscosity measurements were made using a Cannon glass capillary viscometer. Solutions were prepared and stirred overnight. The viscometer was placed in a constant temperature bath for 15 minutes before measurements were made. For each solution the viscosity was measured at least three times and an average of the readings was reported.

### Refractive Index

Solutions of asphaltenes were prepared at concentrations of 8 g/L and were stirred overnight. An ATAGO refractometer equipped with a digital thermometer was used at a constant temperature of 25.6 Celsius degrees.

### Diffuse Reflectance

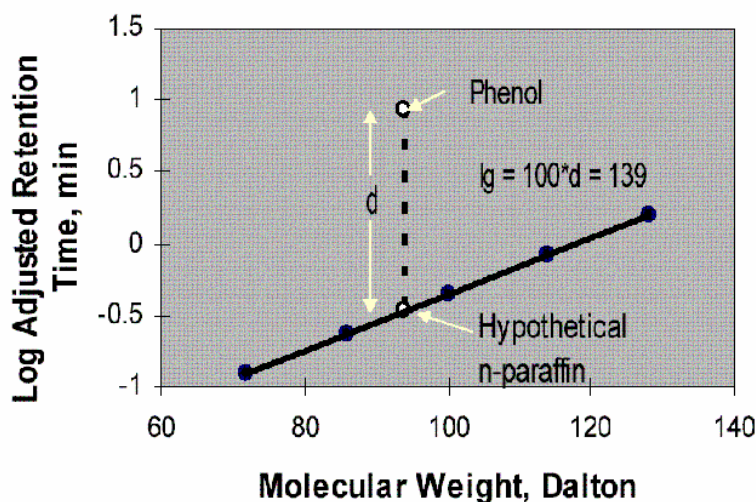
Dried asphaltenes were evacuated at 50<sup>o</sup> C for two hours and then stored in a dessicator. Approximately 0.05 g of asphaltenes were ground with an agate mortar and pestle and physically mixed with 0.200 g of KBr. and. One cup was filled with this mixture, while another cup was filled with KBr in a Pike diffuse reflectance apparatus. A Midac Series M infrared spectrophotometer was aligned and then the background was established using pure KBr. Three thousand scans were run at a resolution of 8 cm<sup>-1</sup> for the background. The asphaltene-KBr mixture was then placed in the path of the IR beam and scanned 2000 times at a resolution of 8 cm<sup>-1</sup>.

## Iatroscan Analysis

Samples were first deasphalted in accordance with ASTM D3279 to yield maltenes. The maltenes were adsorbed on 5 micron silica-gel and fractionated by upward elution on silica-gel coated glass rods using pentane to separate the saturates, and then a toluene/chloroform solution to separate the resins from the aromatics. The three separated fractions were then burned from the chromarods using flame ionized detection (FID) and flame thermionic ionization detection systems.

## Inverse Gas Liquid Chromatography

A Varian 3600 CX gas chromatograph with a flame ionization detector and helium carrier gas was used in the Inverse Gas Liquid Chromatography (IGLC) experiments. 1.0 g of asphalt was dissolved in 10 mL of toluene. Nitrogen gas at a pressure of 5 psig was used to load the solution onto a 0.53mm x 30 m untreated fused silica column mounted horizontally in a water bath at room temperature. After five loops of the column were filled, one end of the column was removed from the asphalt solution and nitrogen forced the solution through the column. This process was repeated twice. The nitrogen pressure was increased to 29 psig and the temperature of the water bath was increased to 40°C. The column was left in the bath for one hour to evaporate the solvent toluene. The column was placed in the Varian 3600 CX and conditioned in a He flow of 1 ml/min for 30 minutes. Each blend was oxidized for 3 hours at 130°C, by replacing the helium carrier gas with dry air. Retention times of methane, heptane, octane, nonane, decane, and phenol were measured on each asphalt before and after oxidization. Methane was not held up significantly by the asphalt, so its retention time was essentially the time taken for the carrier gas to move through the column. The retention time of methane was subtracted from the retention times of each of the hydrocarbons to obtain an adjusted retention time. A graph of the logarithm of the adjusted retention times versus molecular weight of the hydrocarbons is linear, as shown in Figure 1.



**Figure 1. Typical Calibration Curve for Hydrocarbon IGLC**

## **Results and Discussion**

### **Physical Tests**

Based on physical testing by AHTD Materials Laboratory, blends met the Superpave™ grade specification.

### **Iatroscan Analysis**

Compositions of asphalt blends are shown in Table 1.

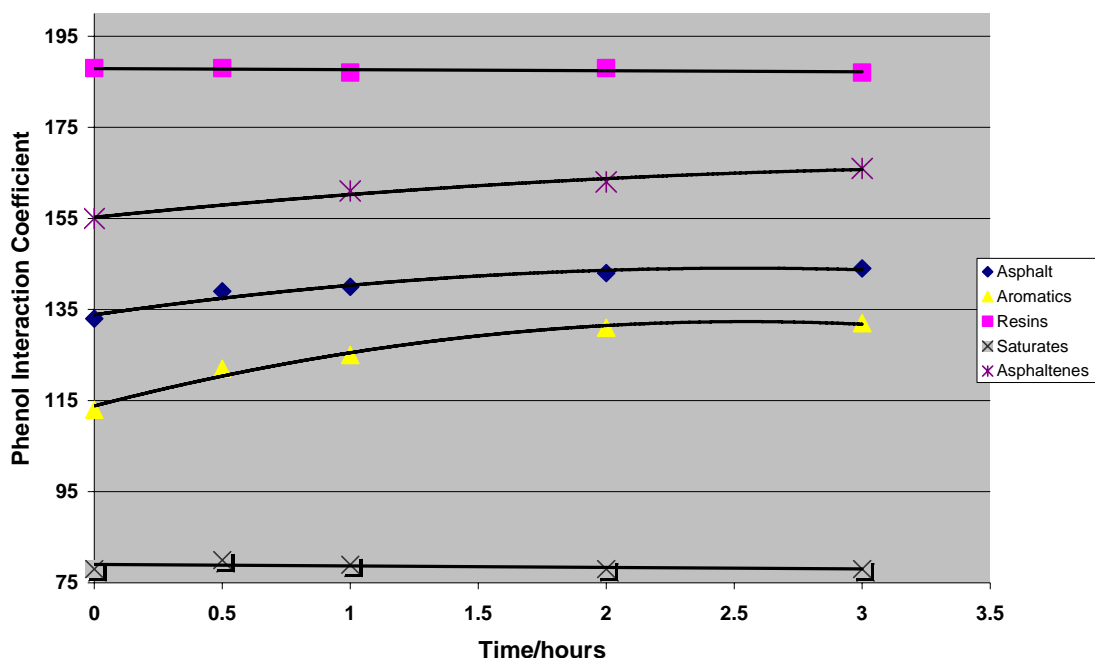
**Table 1. Iatroscan Analysis**

Sample	Performance Grade	% Air Blown	Wt % Asphaltenes	Wt % Resins	Wt % Aromatics	Wt % Saturates
C	PG64-22	0	7.8	22.9	61.5	7.8
C	PG64-22	39	16.1	18.0	59.2	6.7
A	PG67-22	0	10.6	68.6	14.0	6.8
A	PG64-22	50	14.6	52.7	13.6	19.1
B	PG67-22	0	14.2	67.3	12.5	6.0
B	PG67-22	27	15.0	66.6	12.8	5.6

These data indicate significant differences among these three feedstocks. The non air-blown asphalt C is highly aromatic, while the A and B feedstocks have high resin content. Upon air blowing, the asphaltene content of each increases, generally at the expense of the other three fractions. One disturbing item in Table 1 is the similarity in the B samples. Reliable sources have stated that Company B does not specifically air-blow its asphalt, however, air is introduced as molten asphalt is pumped from the refinery to storage tanks. It was for this reason that the third feedstock from Company B was brought into this study. This asphalt was used in MBTC 2049 “Physical and Chemical Characteristics of Superpave™ Binders Containing Air-Blown Asphalt”. Using Company C samples ensured that two blends in this study were not air-blown.

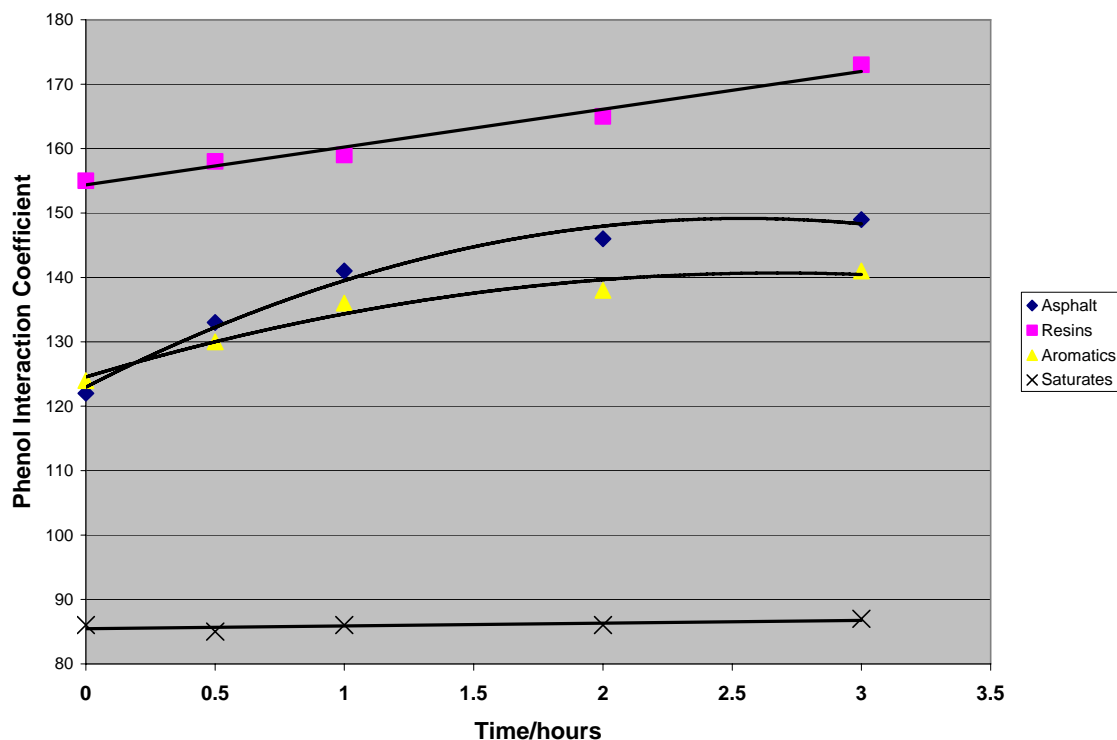
### **IGLC**

Figures 2-5 show phenol interaction coefficients for asphalts and their components before and after oxidation.



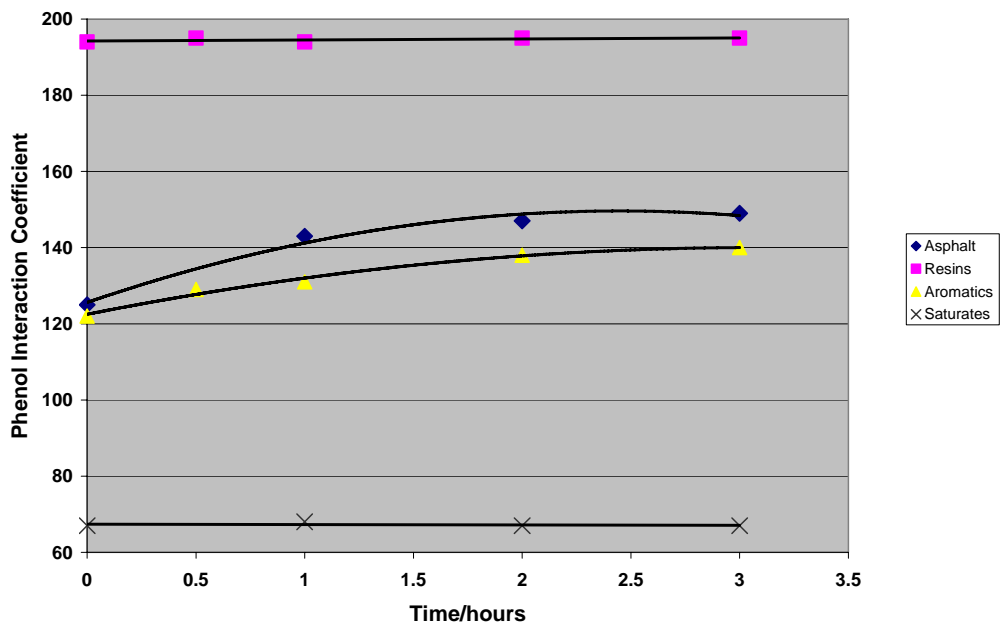
**Figure 2. Phenol interaction coefficients for 100% air-blown asphalt from Company C.**

The asphalt sample used to obtain data for Figure 2 was 100% air-blown asphalt. This was used and compared with a Company C asphalt that had no air-blown component. This was done in hopes of identifying the largest possible differences between the aging behavior of the components of air-blown and non air-blown asphalt. In Figure 2 it appears that saturates and resins undergo no further oxidation, while there is a modest oxidation of aromatics and asphaltenes. Figure 2 also indicates that the resins of this asphalt are significantly more polar than are the asphaltenes. This is an unusual result in light of work done by Goual, et al, (5) where dipole moments of asphaltenes in a given petroleum fluid were always greater than that of resins from the same fluid.



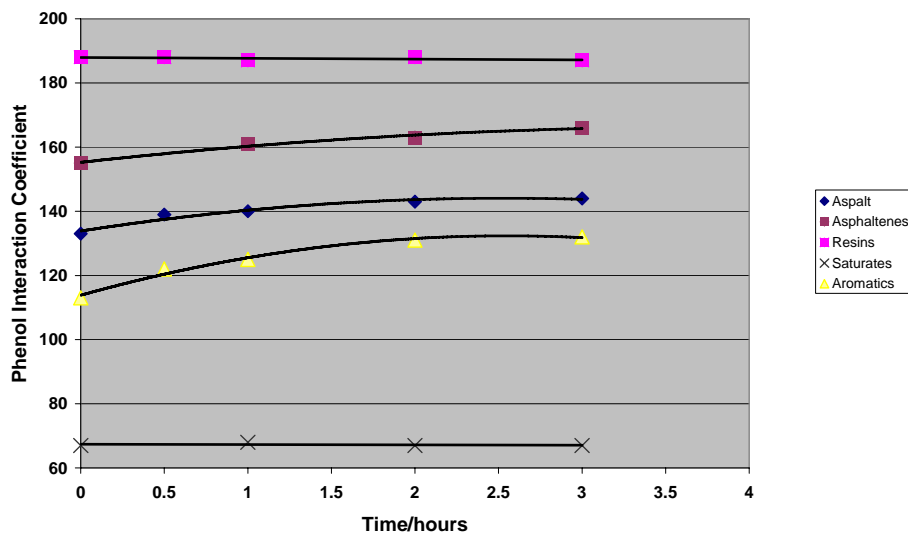
**Figure 3. Phenol interaction coefficients for PG64-22 non air-blown asphalt from Company C.**

Figure 3 shows IGLC data for Company C's PG64-22 with no air-blown material. These data show resins and aromatics undergoing subsequent oxidation under these conditions, while no further oxidation of the saturates fraction is observed. Asphaltenes do not appear in Figure 3 because they precipitated in the capillary column. There appears to be no important similarities in the IGLC data of Company C's air-blown and non air-blown asphalt.



**Figure 4. Phenol interaction coefficients for PG67-22 non air-blown asphalt from Company A.**

Figure 4 shows aging of Company A's PG67-22 non air-blown asphalt is not due to the aging of saturates and resins. Aromatics show further aging, however, the aging behavior of asphaltenes was not measured because of precipitation in the capillary column.



**Figure 5. Phenol interaction coefficients for Company A's 100% air-blown asphalt.**

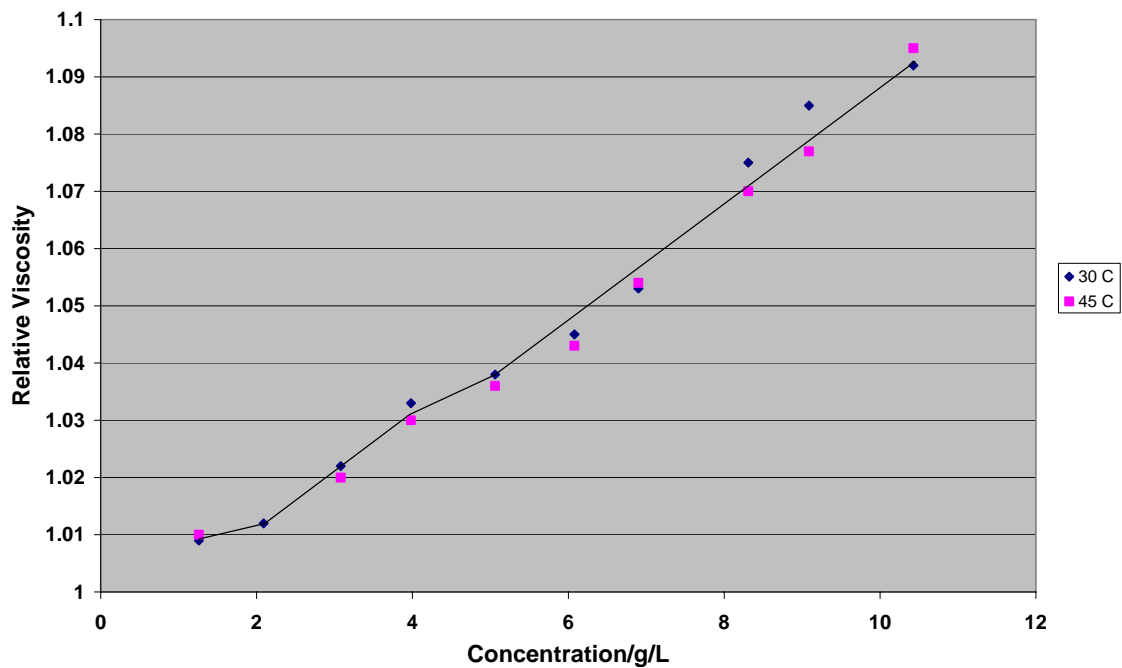
Figure 5 shows asphaltenes with higher phenol interaction coefficients than resins. There is modest subsequent oxidation of this asphalt and its fractions. Once again, there appears to be no trends or regular differences between Company A's air-blown asphalt fractions and its non air-blown fractions.

IGLC data were not collected for Company B's asphalt samples. The technique did not yield data that would be of any great use for the rest of this project.

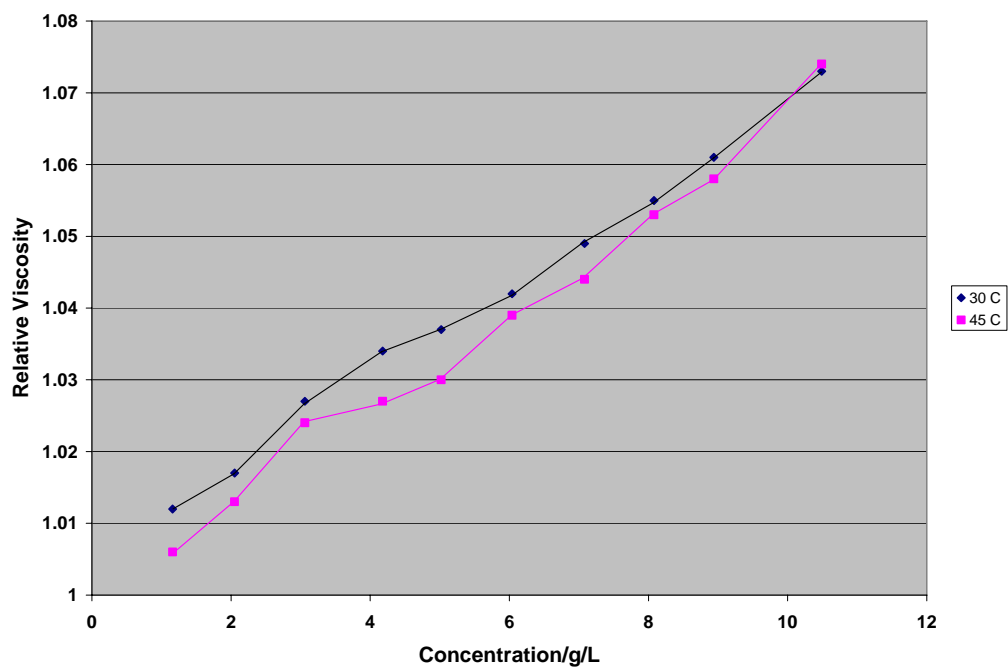
The fact that toluene solutions of asphaltenes from the air-blown asphalts could be loaded onto the capillary column while precipitation occurred in the column with solutions of asphaltenes from non air-blown asphalts suggested differences exist between the toluene solutions of the two types of asphaltenes. Solutions of asphaltenes from different types of asphalt became the focus of the rest of this project. Asphaltenes did offer the advantage that they could be purified to a greater extent than the three other SARA fractions. The question at this point was whether or not these differences were large enough to detect and possibly could be used to detect the presence of air-blown asphalt.

## **Viscosity Measurements**

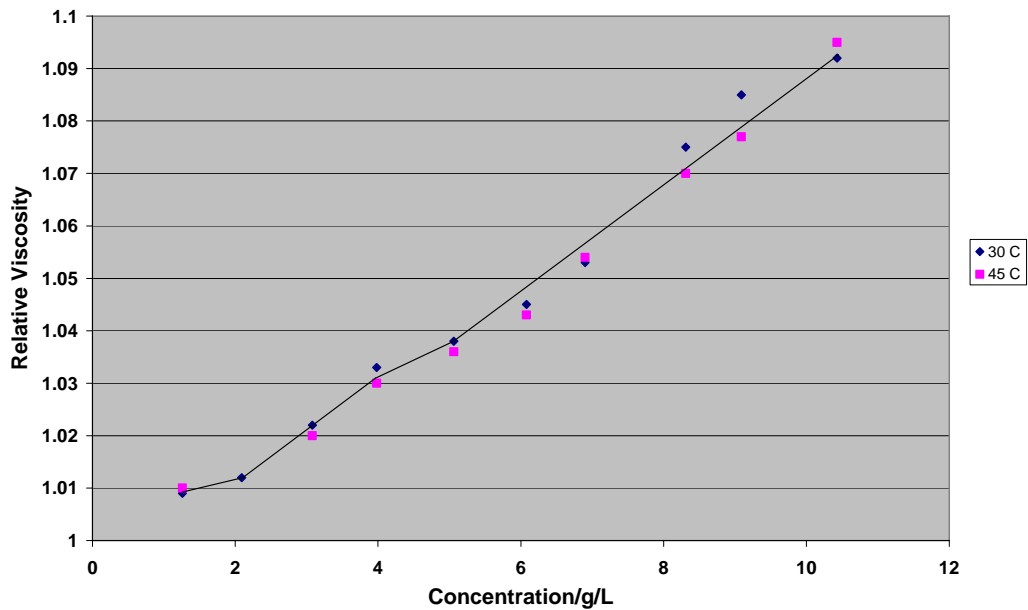
Viscosity measurements were made at a variety of different concentrations and temperatures for toluene solutions of asphaltenes. The most interesting data was for solutions of concentrations between 1 and 10 g/l and at temperatures of 30°C and 45° C. Figures 6-11 present these data.



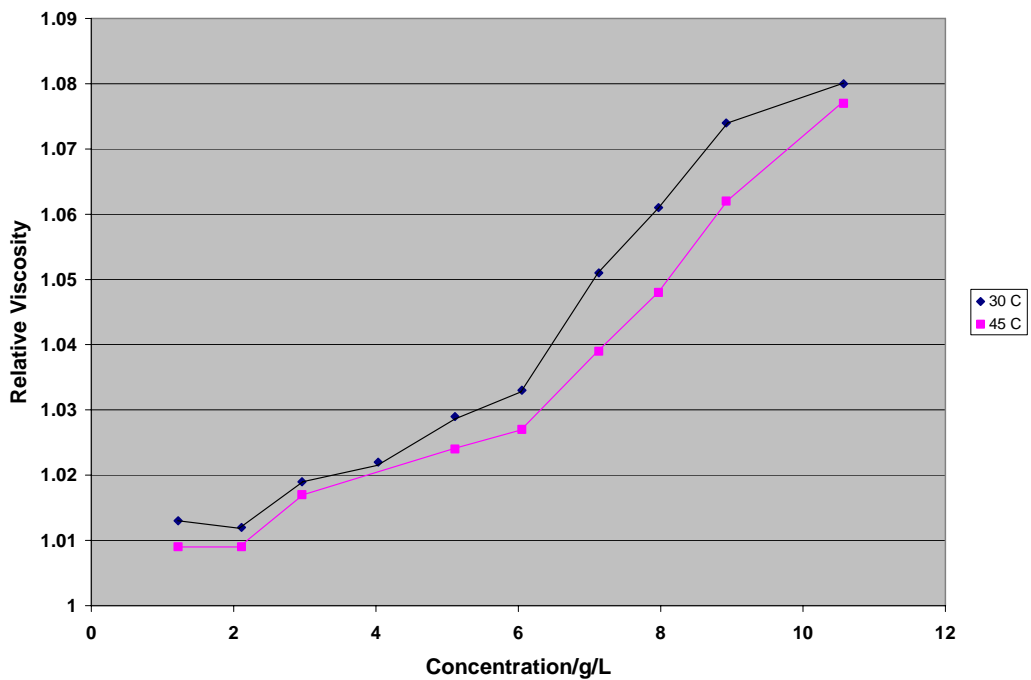
**Figure 6.** Relative viscosities of toluene solutions of asphaltenes from Asphalt C PG64-22 air-blown blend (39% air-blown asphalt).



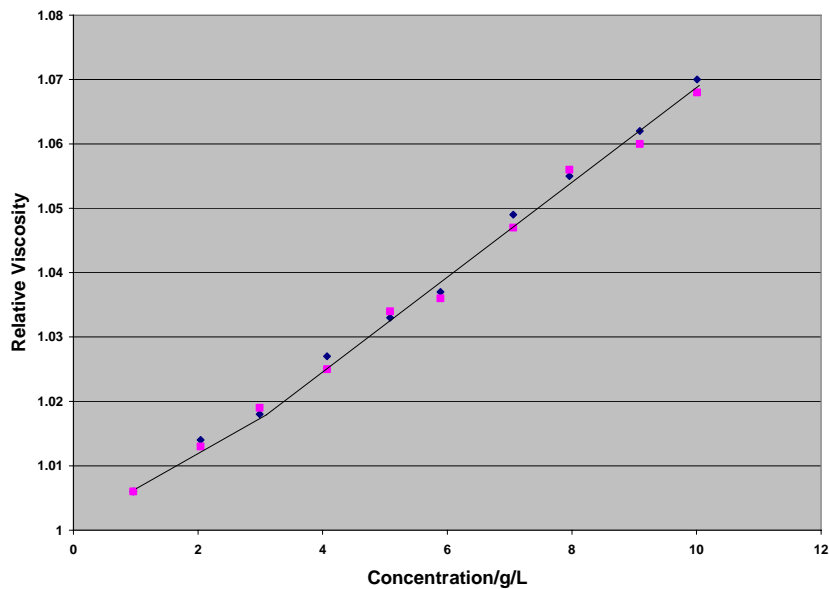
**Figure 7.** Relative viscosities of toluene solutions of asphaltenes from Asphalt C PG64-22 non-air blown blend.



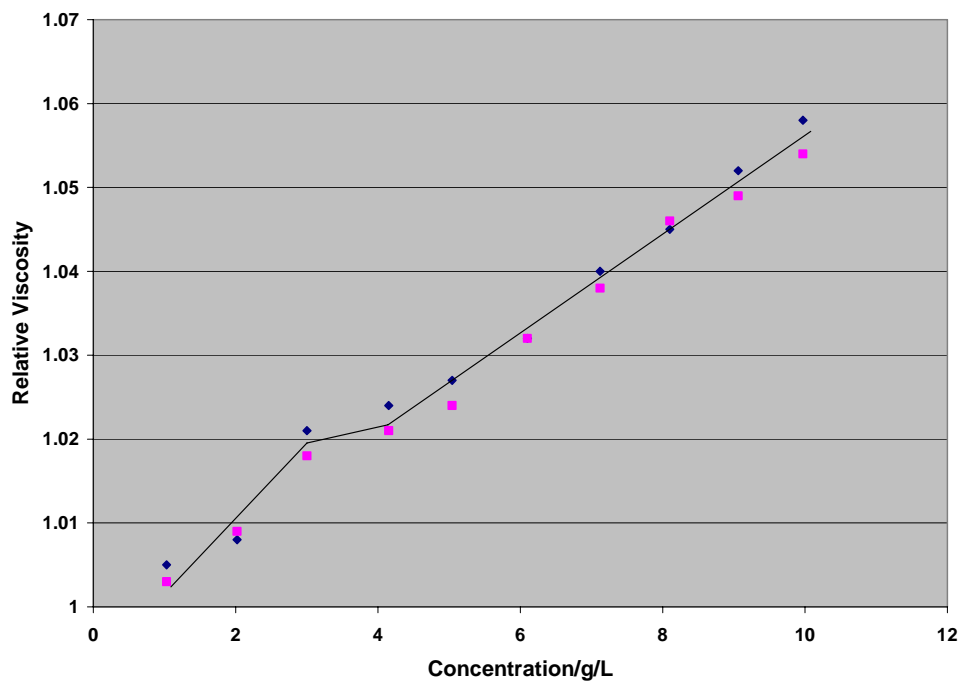
**Figure 8.** Relative viscosities of toluene solutions of asphaltenes from Asphalt A PG67-22 air-blown blend (50% air-blown asphalt).



**Figure 9.** Relative viscosities of toluene solutions of asphaltenes from Company A PG7-22 non air-blown blend.



**Figure 10.** Relative viscosities of toluene solutions of asphaltenes from Asphalt B PG67-22 air-blown blend (27 % air-blown asphalt).



**Figure 11.** Relative viscosities for toluene solutions of asphaltenes from Asphalt B PG67-22 non air-blown blend.

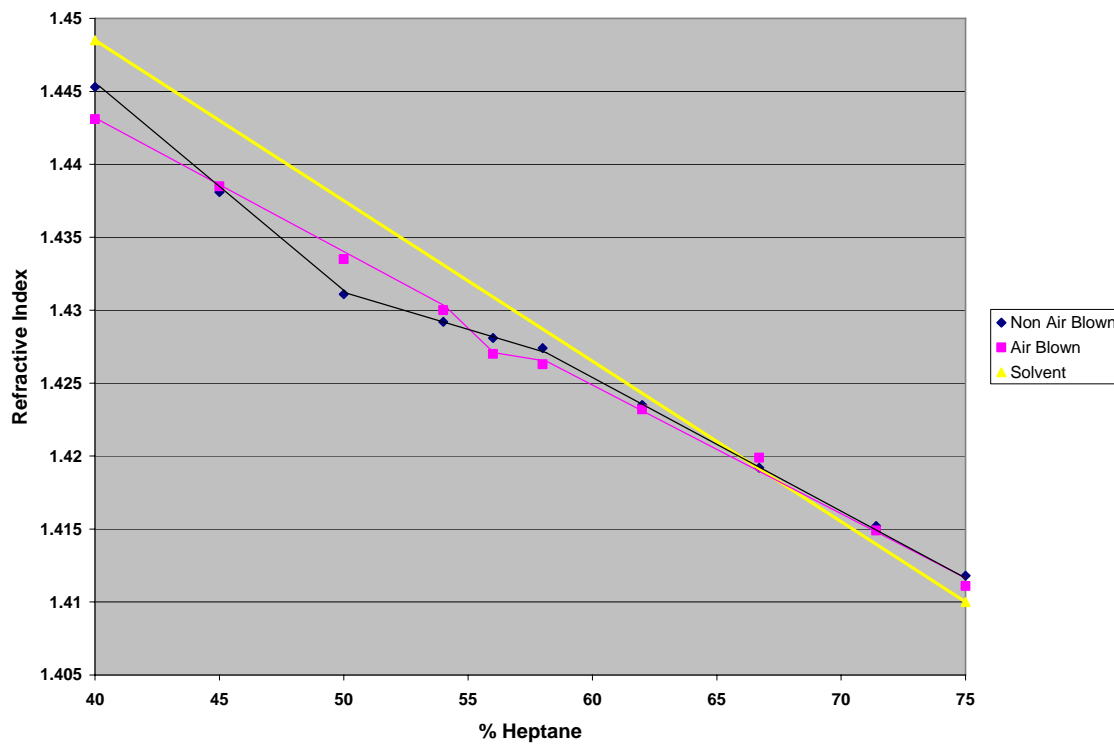
Viscosities plotted in figures 6-11 are viscosities relative to the solvent toluene. For Companies A and C air-blown blends, there are no changes in relative viscosities of asphaltene solutions at 30° and 45°C, whereas there are differences in relative viscosities for solutions of asphaltenes originating from non air-blown blends. If air-blown asphaltenes are more polar than asphaltenes from non air-blown blends, then the intermolecular forces between air blown asphaltene molecules will be greater than intermolecular forces between non air-blown asphaltenes. Raising the temperature from 30° to 45° C provides enough energy to separate non air-blown asphaltenes thus producing smaller particles and lower relative viscosities.

The data from asphaltene solutions from Company B air-blown and non air-blown asphaltenes do not indicate much difference in relative viscosities at 30° and 45°C. This provides additional support that Company B's PG67-22 "non air-blown" blend may be air-blown at the refinery as it leaves the distillation tower.

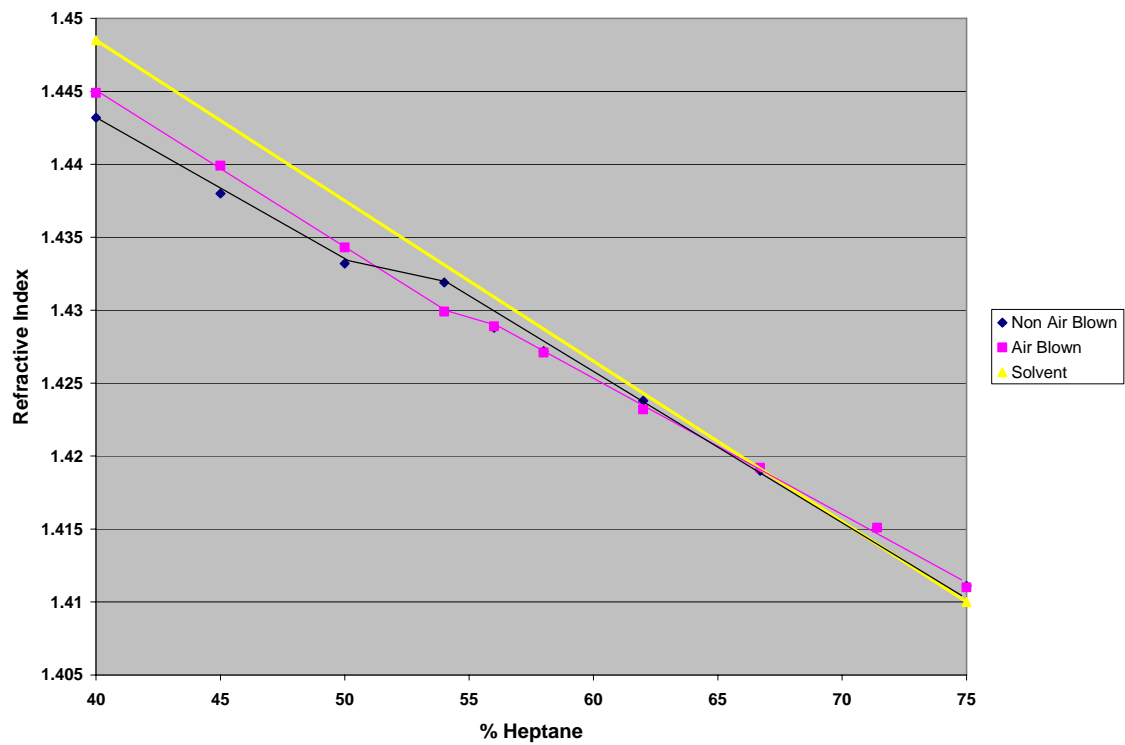
Another feature in Figures 6-11 is the breaks in the curves which presumably occur because of asphaltene aggregation (6). Non air-blown blends C and A each have a break around 3 and 6 g/l, while C and A air-blown blends have breaks at 2 and 5 g/L. If air-blown asphaltenes are more polar than non air-blown asphaltenes, then the greater attractive force between air-blown asphaltenes could account for the lower aggregation concentrations of 2 and 5 g/L. For non air-blown asphalt B there are breaks at 3 and 4 g/L, while air-blown B has only one break at 3 g/L.

## **Refractive Index Measurements**

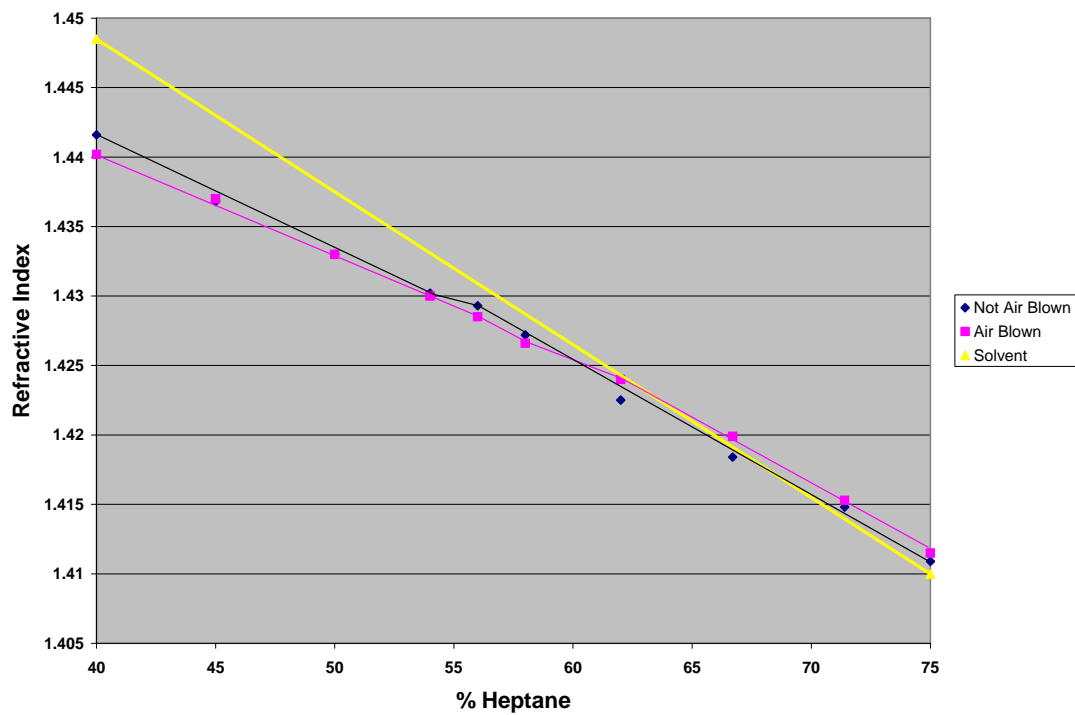
To further study asphaltene solutions, refractive indexes were obtained on heptane-toluene (heptol) solutions. Asphaltenes from air-blown asphalt appear to be larger (7) and more polar than asphaltenes from non air-blown asphalt (8). Based on this information it would seem that if one titrated toluene solutions of asphaltenes with heptane that the solution would become more non polar as heptane is added, and precipitation should occur at lower heptane levels in solutions of asphaltenes obtained from air-blown asphalt than in solutions of asphaltenes obtained from non air-blown asphalt. Refractive index measurements and solubility studies show just the opposite occurs. Figures 12-14 show refractive index data for heptol solutions ranging from 40 volume percent to 75 volume percent heptane. The air blown asphalts in these figures are blends containing 50, 39, and 27 percent air blown asphalt for Company A, B, and C asphalts, respectively.



**Figure 12.** Refractive index of heptol solutions of asphaltenes from Company A asphalt.



**Figure 13.** Refractive index of heptol solutions of asphaltenes from Company C asphalt.



**Figure 14.** Refractive index of heptol solutions of asphaltenes from Company B asphalt.

Precipitation occurs at the concentration at which the refractive index line breaks toward the solvent line. For Company A and C non air-blown asphaltene solutions this break occurs at 50 volume percent heptane, while the break occurs for solutions of air-blown asphaltenes occurs at 55 volume percent heptane. Once again there is an almost insignificant difference between the refractive index data for asphaltene solutions from Company C air blown and non air-blown blends.

This difference in solubility is surprising since it is generally expected that air-blown asphaltenes are more polar than non air-blown asphaltenes. The solubility difference might be explained if the more polar asphaltenes form a more open aggregate in solution than do non air-blown asphaltenes. The structure or geometry of air-blown asphaltenes may not allow them to pack as tightly as non air-blown asphaltenes. The open structure will allow toluene to more easily solvate air-blown asphaltenes and keep them in solution longer than non air-blown asphaltenes. To help confirm the data on precipitation from refractive index data, titrations were carried out to directly observe precipitation.

### **Solubility Experiments**

Differences in solubility behavior of asphaltenes were observed in heptane-toluene solutions. When heptane was added to toluene solutions of asphaltenes, it required more heptane to precipitate asphaltenes from air-blown asphalt than it does asphaltenes from non air-blown asphalt. Each of the following solutions had asphaltenes at a concentration of 0.100 g in 2.00 mL of toluene. Solutions were stirred from 12 to 15 hours to ensure equilibrium was achieved. Heptane was then added with vigorous stirring using a micropipette. After stirring for 30 minutes, samples were centrifuged at 3500 rpm for 30 minutes. Precipitates were noted by direct observation.

<u>Non air-blown asphaltene</u>	<u>Amount of heptane added (mL)</u>	<u>Precipitate</u>
<u>In solution</u>		
PG64-22 Company C	1.60	yes
	1.70	yes
	1.80	yes
PG67-22 Company A	1.60	yes
	1.70	yes
	1.80	yes
PG67-22 Company B	1.60	no
	1.70	no
	1.80	yes

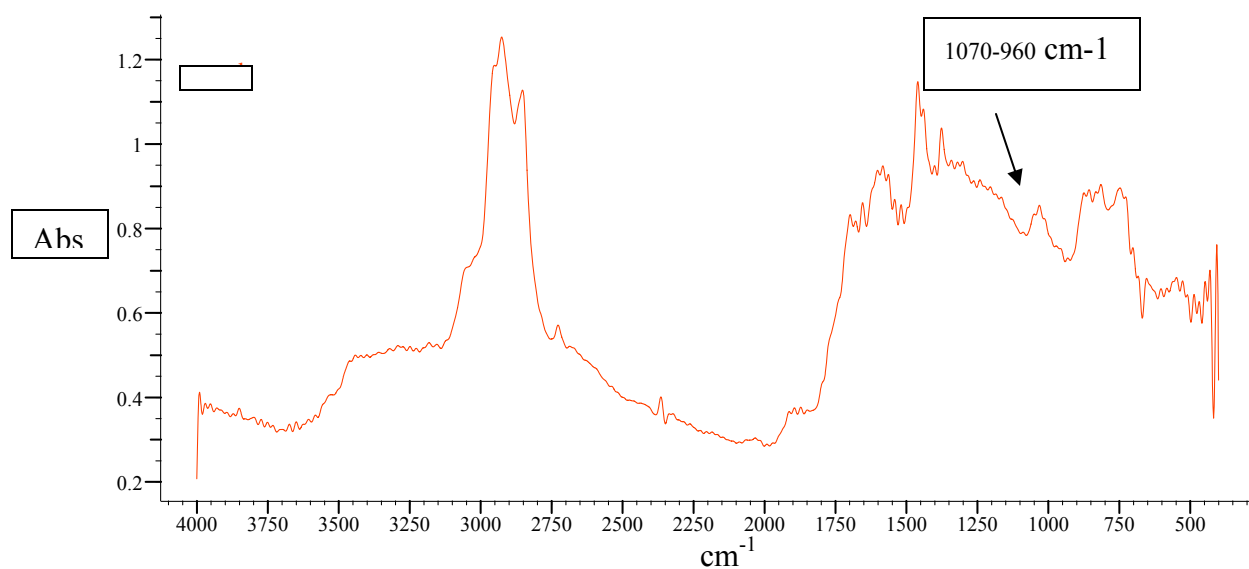
<u>Air-blown asphaltene</u>	<u>Amount of heptane added (mL)</u>	<u>Precipitate</u>
<u>In solution</u>		
PG64-22 Company C	1.60	no
	1.70	no
	1.80	no
PG67-22 Company A	1.60	no
	1.70	no
	1.80	no
PG67-22 Company B	1.60	no
	1.70	no
	1.80	no

**Table 2. Solubility data for asphaltene solutions titrated with heptane.**

In other words, for toluene solutions of asphaltenes obtained from non air-blown blends, precipitation occurs when 1.60 or 1.70 mL of heptane are added. Precipitation does not occur for toluene solutions of asphaltenes obtained from blends containing air-blown asphalt. The C sample contains about 35% air-blown material, the A sample had 50% air-blown material, and the B samples contain 27% air-blown material. These data are consistent with refractive index data that indicated non air-blown asphaltenes precipitated at lower heptane volume percent than air-blown asphaltenes.

## Diffuse Reflectance Spectroscopy

Infrared and diffuse reflectance infrared Fourier Transform (DRIFT) spectroscopy have been used to study weatherability of coating asphalts (9) and to study structural features of resins, asphaltenes, and kerogen (10). Figure 15 shows a typical DRIFT spectrum for an asphalt used in this study.



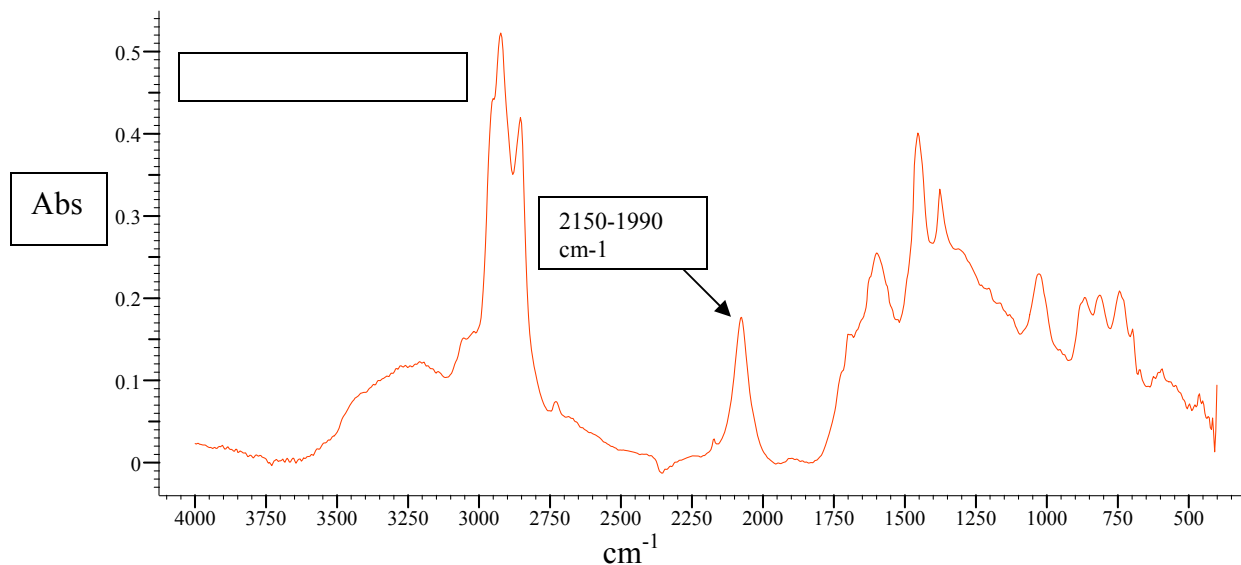
**Figure 15. DRIFT of air blown blend plotted as absorbance versus wavenumber.**

Assignments of peaks are given in Table 3.

Wavenumber (cm <sup>-1</sup> )	Type of Functionality
3100-3000	Aromatic stretch
2950 shoulder	Asymmetric CH <sub>3</sub> - stretch
2925	CH stretching
2855	CH stretching
1820-1650	Aldehyde, ketone and acidic carbonyl
1600	Aromatic C=C
1460	C—CH <sub>3</sub> and —CH <sub>2</sub> —asymmetric stretch
1375	Symmetric C—CH <sub>3</sub> bend
1070-960	C—N, C—S, C—O stretch
880-790	Aromatic C—H stretch

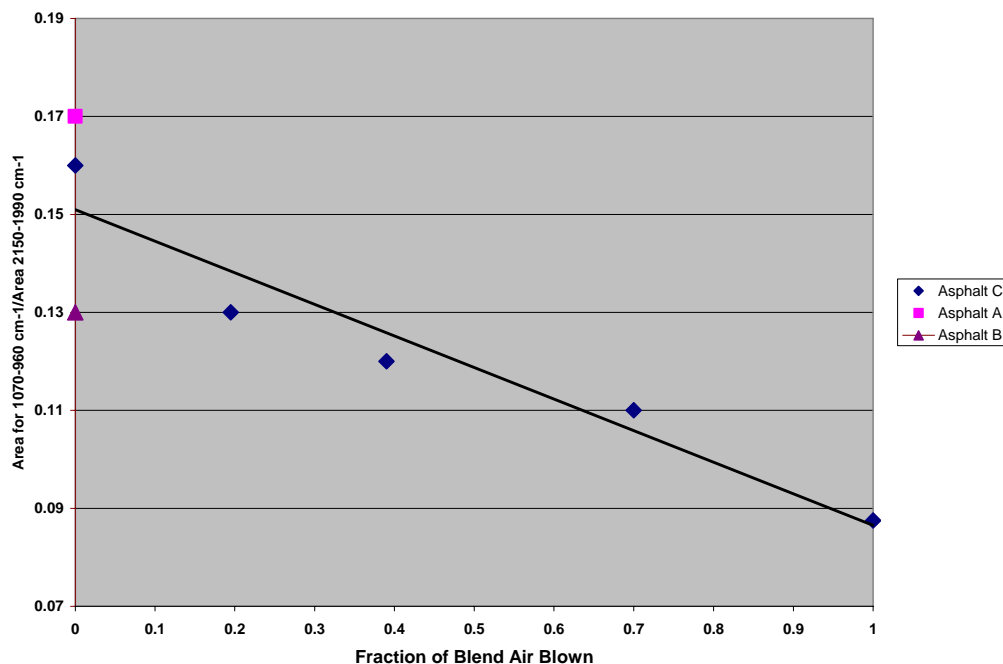
**Table 3. Peak assignment for DRIFT spectra.**

After studying several spectra, it appeared that the area of the peak from 1070 to 960 cm<sup>-1</sup> (shown under arrow in Figure 15) was smaller for asphaltenes from air-blown blends. This seems reasonable in that C—N, C—S, and C—O groups can be oxidized. Oxidation at these sites during air blowing would decrease the area from 1070 to 960 cm<sup>-1</sup>. To put this decrease on a quantitative basis, an internal standard was used. KCN was chosen because it has a peak at 2150 to 1990 cm<sup>-1</sup> that does not interfere with asphaltene spectra and KCN has no peak that interferes in the 1070 to 960 cm<sup>-1</sup> range. Equal weights of KCN and asphaltene were mixed and ground in a mortar and pestle. After thorough mixing, a small amount was physically mixed with 0.200 g of KBr. A diffuse reflectance cup was filled with this mixture and spectrum was obtained. The spectrum in Figure 16 shows the cyanide peak in an asphaltene spectrum.



**Figure 16. DRIFT spectrum of asphaltene with  $\text{CN}^-$  present as an internal standard.**

The ratio of the area for the region  $1070\text{-}960\text{ cm}^{-1}$  to the area in the region  $2150\text{-}1990\text{ cm}^{-1}$  was plotted versus percent air-blown asphalt in the blend. This is shown in Figure 17.



**Figure 17. Plot showing linear relationship between the ratio of areas  $1070\text{-}960\text{ cm}^{-1}$  to  $2150\text{-}1990\text{ cm}^{-1}$  versus fraction of air-blown asphalt in blend for Company C asphalts.**

This shows a linear decrease in the area ratios for asphalt C as the fraction of air-blown material in the blend increases. Also shown on this graph are the ratios of these areas for the non air-blown blends from Asphalt A and B. Relative to Asphalts A and C, asphalt B again appears to have relatively small amount of C-N, C-S, and C-O bonds which is consistent with other indications that it is air-blown.

## Conclusions

1. Inverse gas liquid chromatography (IGLC) has shown air-blown blends have higher initial phenol interaction coefficient (Ig) values and these values increase faster upon oxidation than those for non air-blown blends. IGLC work done on SARA fractions did not show any reproducible trends in Ig values for asphalts from different feedstocks.
2. Relative viscosities (relative to the solvent toluene) for solutions of asphaltenes from air-blown blends are the same at 30° and 45°C, while differences in relative viscosities for solutions of asphaltenes from non air-blown blends were observed at these temperatures. This may be a simple test to distinguish between air-blown and non air-blown blends.
3. From relative viscosity data it appears the concentration at which asphaltene aggregation occurs is lower for air-blown asphaltenes than it is for non air-blown asphaltenes. This may support the conclusion that air-blown asphaltenes are more polar than non air-blown asphaltenes.
4. Refractive index data show that when heptane is added to toluene solutions of asphaltenes, non air-blown asphaltenes precipitate before air-blown asphaltenes. This provides evidence that even though air blown asphaltenes are more polar than non air-blown asphaltenes, the structure of aggregates of air-blown asphaltenes must be more open and less tightly packed than aggregates of non air-blown asphaltenes.
5. Precipitation of non air-blown asphaltenes at lower heptane levels was directly observed by titrating toluene solutions with heptane and centrifuging solutions. This may be a simple test to distinguish between air-blown and non air-blown blends.
6. Diffuse reflectance infrared Fourier Transform (DRIFT) spectroscopy indicates air blowing oxidizes carbon-nitrogen, carbon-sulfur, and carbon-oxygen bonds. The peak responsible for C-N, C-S, and C-O stretching (1070-960  $\text{cm}^{-1}$ ) diminishes as the percent air-blown blend in the binder increases. This may be a simple test to distinguish between air-blown and non air-blown blends.
7. Viscosity, refractive index, solubility, and DRIFT data indicate Company B's commercial PG67-22 may be air blown.

## Recommendations

1. More data should be obtained in order to confirm that relative viscosities of toluene solutions of asphaltenes from non air-blown blends do not change when heated from 30° to 45° C. The temperature at which air-blown asphaltene solutions start to show differences in relative viscosity should be identified. It may be possible to heat beyond 45°C and still not see changes in the relative viscosities of air-blown asphaltene solutions. At a higher temperature there might be even greater differences in relative viscosities for non air blown asphaltene solutions and this could provide more confidence in this test.
2. Relative viscosities of toluene solutions of *asphalt blends* should be measured at various concentrations and temperatures. The effect observed at 30° and 45°C might also be observed with these solutions which would eliminate the need for asphaltene separation and simplify this test for air-blown asphalt.
3. Refractive index data should be obtained on toluene solutions of *asphalt blends*. Precipitation may occur with the non air-blown asphalt solutions sooner than with the air-blown blend solutions. This would simplify the precipitation test.
4. Measure relative viscosities and refractive indices of a large number (5-10) non air-blown asphalt blends to develop more confidence in these two tests.
5. Obtain more DRIFT data from asphaltenes of non air-blown blends to determine if a simple IR spectrum could detect the presence of air-blown asphalt.
6. Talk with Company B and see if they admit to letting air come in to contact with molten asphalt in their refinery.
7. Aging studies on commercial samples of Company B asphalt should be conducted to see if they age at rates different than those of known non air-blown blends. An aging study like the one conducted in MBTC 2049 at 80°C and one atmosphere might be useful.

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