T. A. Kubic,[1] *M.S., J.D.; C. M. Lasher,*[2] *B.S.; and James Dwyer,*[3] *Ph.D*

Individualization of Automobile Engine Oils I: The Introduction of Variable Separation Synchronous Excitation Fluorescence to Engine Oil Analysis

REFERENCE: Kubic, T. A., Lasher, C. M., and Dwyer, J., **"Individualization of Automobile Engine Oils. I. The Introduction of Variable Separation Synchronous Excitation Fluorescence to Engine Oil Analysis,"** *Journal of Forensic Sciences*, JFSCA, Vol. 28, No. 1, Jan. 1983, pp. 186-199.

ABSTRACT: Automobile lubricants are frequently encountered at the scene of a crime and are submitted along with standards from the defendant's vehicle in order to establish common origin. The measurement of the total visible fluorescence by emission, synchronous excitation emission, and variable separation synchronous excitation (VSSE) spectra has been shown to individualize motor oils to a high degree. Spectra obtained from specimens at liquid nitrogen temperature increased the discrimination value of these techniques. The data obtained on 61 automobile lubricants is presented and conclusions discussed with particular emphasis on the recently developed VSSE technique.

KEYWORDS: criminalistics, luminescence, petroleum products

In recent years it has become increasingly important to detect, characterize, and attempt to establish the common origin of oil spill specimens. Oil spills from tankers are becoming more frequent, resulting in extensive environmental damage. Individualization of oil specimens is important not only in the enforcement of environmental protection laws and regulations but also for other criminalistics applications. One such application is matching oil left at a crime scene with the oil recovered from the crankcase of the suspect's automobile.

Oils are complex mixtures of organic compounds, primarily of hydrocarbon composition. In general, oils from different sources possess sufficient variability in their composition so that they can be differentiated from one another. As oil is used it undergoes changes, so that even though the same fresh oil is placed into two different engines, it will likely develop unique characteristics through use.

Presently, there is no single method for the individualization of an oil. The U.S. Coast Guard Research and Development Center uses infrared spectroscopy, gas chromatography,

Received for publication 19 April 1982; accepted for publication 25 May 1982.

[1]Detective criminalist, Scientific Investigation Bureau, Nassau County Police Department, Mineola, NY.

[2]Forensic scientist, Criminalistics Laboratory, Suffolk County Medical Examiner's Office, Hauppaugue, NY.

[3]Associate professor of chemistry, C. W. Post College, Greenvale, NY.

thin-layer chromatography, and fluorescence spectroscopy in their basic oil identification system [*1*]. The U.S. Environmental Protection Agency uses gas chromatography, fluorescence spectroscopy, and ultraviolet absorption spectroscopy [*2*]. Both the Environmental Protection Agency and the U.S. Coast Guard believe that fluorescence spectroscopy is singularly the most useful diagnostic tool [*2*]. There are many different techniques of fluorometry that, when used separately or together, will aid in the characterization and individual identification of an oil specimen. The techniques generally used are single wavelength excitation and synchronous excitation. Use of all of the fluorescence techniques however, does not enable the individualization of oil specimens with certainty. This paper describes a new fluorometric method, named by the authors *variable separation synchronous excitation fluorometry* (VSSE). The VSSE method will augment the fluorescence technique previously available and provide a more complete characterization of oil luminescence.

Every molecule possesses a series of closely spaced energy levels in its electronic structure. Absorption of external energy may cause an electron to pass to a higher energy level. The spontaneous return of the excited electron can cause luminescence in the form of either fluorescence or phosphorescence. The former appears at shorter wavelengths and has a faster decay time (10^{-9} to 10^{-6} s) while the latter appears at longer wavelengths and has a longer decay time (10^{-6} to 10 s).

In a spectrofluorescence measurement, there are three intrinsic parameters: the excitation wavelength, the emission wavelength, and the fluorescence intensity. These may be readily represented graphically in a three-dimensional representation. The total fluorescene spectrum of a material can also be visualized as a contour plot. Figure 1 depicts the total fluorescence spectrum of a multicomponent material with three fluorescence maxima, the excitation wavelength, emission wavelength, and fluorescence intensity being represented by the *x*, *y*, and *z* axes, respectively [*3*].

Using single-wavelength excitation fluorescence (also known as *constant excitation fluorometry* and *conventional fluorometry*), the specimen is excited at one discrete wavelength and the fluorescence intensity is recorded as a function of the emission wavelength. The curves generated by the three planes parallel to the *y* axis in Fig. 2 illustrate the spectra that would be recorded for a specimen if three different exciting wavelengths were employed. A disadvantage to conventional fluorometry is that both Rayleigh-Tyndall and Raman scatter occur and may interfere with the analysis. Single-emission fluorometry is similar to single-excitation fluorometry; however, the emission wavelength is constant while the excitation wavelength is varied. Such a measurement would give rise to spectra similar to conventional absorption spectra.

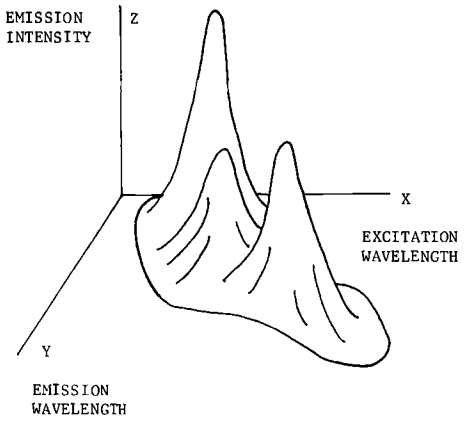

FIG. 1—*Three-dimensional presentation of the total fluorescence spectrum of an oil.*

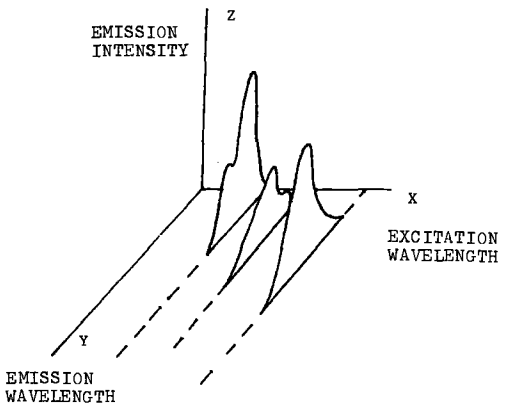

FIG. 2—*Three-dimensional presentation of the emission spectra of the oil in Fig. 1 excited at three wavelengths.*

The idea of synchronous excitation luminescence was suggested by Lloyd [*4*]. Synchronous fluorometry involves the continuous simultaneous scanning of excitation and emission wavelengths, the two being separated by a constant wavelength increment with the emission wavelength monochromator maintained at longer wavelengths. The spectral information obtained is dependent on the wavelength increment and an optimum incremental value must be determined. In Fig. 3 the dashed lines illustrate how the synchronous scan generates a plane at a 45° angle to the x and y axes [*5*]. When synchronous excitation fluorometry is used, the Rayleigh-Tyndall and Raman scatter interferences can be eliminated.

When the techniques of single-wavelengths excitation, single-wavelength emission, and synchronous excitation are used, a simplified contour plot can be depicted. This was demonstrated by Weiner [*6*] and is illustrated in Fig. 4. A method by Freegarde et al proposes the analysis of oils by constructing contour maps [*7*]. Although such projections represent a three-dimensional system, they are extremely time-consuming to construct or require computer services for data manipulation.

Variable separation synchronous excitation fluorescence (VSSE), uses the three parameters of fluorescence to obtain a more complete picture of the total spectrum. As in synchronous fluorometry, the excitation and emission monochromators are simultaneously scanned, but in VSSE the monochromators are scanned at different rates. The different rates enable planes to be constructed through the total spectrum that lie at angles between 45 and 90° to the x-axis. The angle is determined by the differences in the monochromator scanning rates. The emission monochromator must be scanned at a greater rate than the excitation monochromator, which dictates that the plane measured has an angle greater than 45° to the excitation x-axis. By compiling the information obtained from scans at various angles and at different initial monochromator separations, a reasonable estimation of the total three-dimensional fluorescence spectrum is easily assembled without computer services. The VSSE method can be used to generate spectra throughout a large portion of the three-dimensional structure of automobile engine oils.

Experimental Equipment

The fluorescence data on unused motor oils presented were obtained with a Farrand Spectrofluorometer Mark I, employing a corrected excitation module and a synchronous scanning accessory. The instrument was specially modified by the manufacturer to the authors'

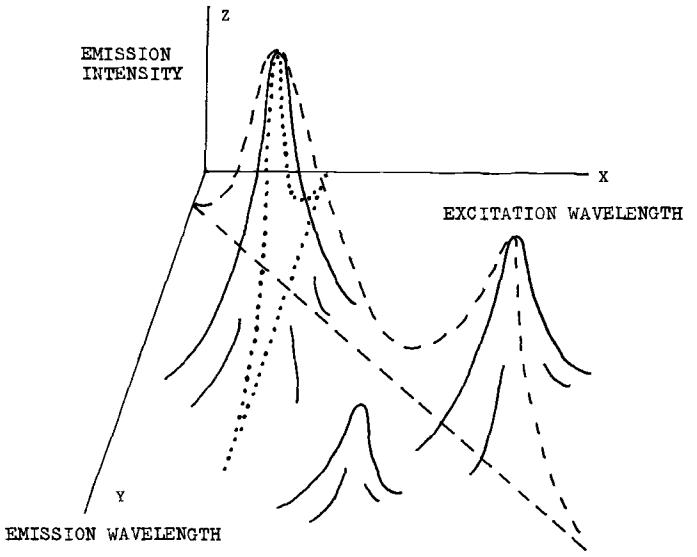

FIG. 3—*Representation of the spectra obtained by single-wavelength excitation (dotted line) and synchronous excitation (dashed line), where the solid lines represent the total spectrum of the hypothetical mixture.*

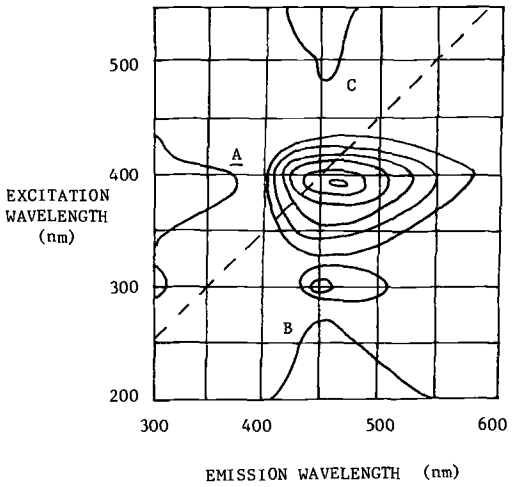

FIG. 4—*Three-dimensional contour plot. Curves A and B are the conventional excitation and emission spectra, respectively. Curve C is the synchronous spectrum taken along the dashed line and projected onto the emission wavelength axis.*

specifications to allow synchronous scanning of the excitation and emission monochromators at different rates. Luminescence was recorded on an *x-y* recorder as a function of either the excitation or emission wavelengths, as indicated. Excitation radiation was supplied by a high pressure 150-W xenon DC arc lamp. Sample luminescence was detected with an RCA Model 4818 photomultiplier tube. A Farrand cryogenic assembly was used for all low-temperature determinations. Cyclohexane (Matheson, Coleman, and Bell) and methylcyclohexane (East-

man) were spectroquality grade and used as supplied. Sixty-one unused lubricants were obtained from various commercial sources. The brands and grades of these samples are listed in Table 1.

Discussion and Results

A reference specimen of oil was placed into a solution with cyclohexane and scanned twice weekly for one month to verify reproducibility and to establish if aging caused any changes in composition. The scans were performed synchronously because a very distinctive spectrum is obtained with a wavelength separation of 20 nm. It was established that after one month, no noticeable change could be observed in the intensity or shape of the spectra obtained, and therefore no major change in composition is expected to occur upon leaving the oils in solution for periods less than 30 days.

TABLE 1—*Oil specimens.*

1. Getty Veedol 10/40 SAE 10W-40
2. Getty Veedol Veelube nondetergent SAE-30
3. Getty Veedol HD SAE 20-20W
4. Hess Motor Oil (green label) SAE 30
5. Hess Multiviscosity (gold label) 10W-40-HD
6. Hess Heavy-Duty (blue label) SAE 30
7. Exxon extra (blue label) SAE 10W-20W-30
8. Exxon Oilex (all red label) SAE-30-detergent
9. Exxon Uniflo (gold label) SAE 10W-20W-40
10. Exxon Plus (red label) SAE 30
11. Texaco Havoline Super Premium SAE 10W-40 HD
12. Texaco Havoline Motor Oil SAE 20-20W HD
13. Texaco Motor Oil SAE 30 HD
14. Sunoco Special long mileage SAE 10W-40
15. Sunoco Dynalube 10W-30
16. Sunoco Sunlube SAE 30
17. Amoco LDO super permalube (gold label) SAE 10W-40
18. Amoco Super Permalube (silver label) SAE 10W-30
19. Amoco Permalube (blue/white label) SAE 30 HD
20. STP Motor Oil 15 000 mile SAE 10W-20W-50
21. Shell Super X SAE 10W-20W-30
22. Shell X-100 Multigrade (white label) 10W-20W-40
23. Shell X-100 (red/white label) SAE 30
24. Chevron Custom (gold label) SAE 10W-40
25. Chevron Special (blue label) SAE 30
26. Gulf Gulflube-Single SAE 30
27. Gulf Gulf Pride-Multi-G SAE 10W-20W-40
28. Mobil Super (all gold label) 10W-40
29. Mobil Special (gold/white label) SAE 10W-30
30. Mobil Heavy-Duty (blue/white label) SAE 30
31. Mobil 1 (synthesized) SAE 5W-20
32. BP Extra Duty 10W-30
33. BP Super Visco-Static SAE 10W-40
34. All Weather Premium 2500 mile Penfield Pet. Prod. Mineola SAE 30
35. All Weather Multi-Grade Penfield Pet. Prod. Mineola, N.Y. 10W-20W-40
36. Pennzoil Multi-Vis wZ-7 HD SAE 10W-30
37. Pennzoil Racing Oil SAE 30
38. Pennzoil 4 Stroke Motorcycle Oil SAE 20W-50
39. Oilzum Motorcycle Oil SAE 50
40. Oilzum HP Racing Oil SAE 30
41. Oilzum Special Motor Oil HD SAE 10W-40
42. Oilzum Special Motor Oil HD SAE 20W-50
43. Kendall Superb Multi-Vis SAE 10W-20W-30
44. Kendall Dual Action SAE 40 HD-1
45. Kendall GT-1 Racing Oil SAE 30
46. Castrol Grand Prix Motorcycle Oil 4 Cycle SAE-30
47. Castrol Regular Motor Oil (green label) SAE 30
48. Castrol Heavy Duty Motor Oil SAE 30
49. Quaker State Deluxe SAE 10W-40 HD
50. Quaker State Super Blend SAE 10W-20W-30 HD
51. Quaker State HD Oil SAE 30
52. Valvoline XLD SAE 10W-20W-40
53. Valvoline HP Racing Oil SAE 30
54. Valvoline HD Super HPO SAE 30
55. Valvoline All-Climate HD SAE 10W-20W-40
56. Valvoline Non Detergent SAE 30
57. Quaker State Multi-Purpose Grease Lithium E.P. NLGI Grade 3
58. Quaker State High Performance Gear Oil SAE 90 E.P.
59. Quaker State Special Wheel Bearing Grease
60. Prestone Brake Fluid (Hi Temp)
61. Composite I

Thruston and Knight found that the intensity and shape of oil fluorescence spectra depend significantly on their concentrations [*8*]. At higher concentrations suppression of fluorescence results from the inner filter effect and variations in the spectra generated are experienced [*9*]. The optimum concentration for fluorescence measurements was found to be approximately 10 to 20 ppm by weight in cyclohexane for room temperature measurements [*3*] and in methylcyclohexane at cryogenic temperatures [*10*]. Impurities in the solvent can yield spectra that coincide with those of oils, but this effect can be minimized if high-quality spectral grade solvents are used or a suitable purification system is used. Solvent blanks were scanned by single-wavelength excitation, synchronous excitation, and VSSE fluorescence to retain as references, and any peaks appearing on these spectra were disregarded in the analysis of the oil spectra.

In all figures, the *y*-axis is in microamperes. The figures do not display the absolute current but rather the relative instrument meter deflection. The absolute current in microamperes is obtained by multiplying the meter reading by the range setting on the Mark I.

The best spectral resolution was obtained with an excitation slit that gave a spectral band pass of 10 nm and an emission slit that gave a spectral band pass of 2 nm. The angles of the generated planes from the VSSE techniques are determined by the following equation:

$$(\theta) = \text{tangent}^{-1} \text{(emission scan speed)/(excitation scan speed)}$$

In practice, the excitation monochromator was set at 250 nm initially and the emission monochromator was set for the appropriate initial separation. The appropriate scanning rates to generate the required angles were set. The current instrumental design dictates that the fluorescence intensity be plotted against the excitation wavelength when VSSE is used. This difference in the format of the VSSE spectra and the spectra obtained with the other fluorescence techniques can be reconciled by future redesigning of the electronics.

The three fluorescence techniques of single-wavelength excitation, synchronous excitation, and VSSE used at room temperature can also be employed in analyses at cryogenic temperatures. An increase in resolution of spectral structure is obtained at cryogenic temperatures (77 K). The cyclohexane solutions formed opaque snows when frozen. Therefore, methylcyclohexane was chosen as the cryogenic solvent because it forms a clear glass when frozen and gives more reproducible spectra [*11*].

The first type of fluorescence measurements performed on the oil specimens was a conventional emission scan at a constant excitation wavelength of 255 nm. The 61 specimens could be separated into eight different groups after this analysis (Table 2). The largest group contained 26 specimens as noted. A representative spectrum from this group is presented in Fig. 5.

All the oil specimens were next synchronously scanned with a constant wavelength separation of 20 nm, beginning with the excitation monochromator set at 230 nm. As shown in Table 3, the synchronous scans led to a further discrimination within the previous eight

TABLE 2—*Separation of the 61 oil specimens by using constant excitation fluorescence.*

Group	Number of Oils in Group
A	2
B	3
C	2
D	9
E	12
F	6
G	26
H	1

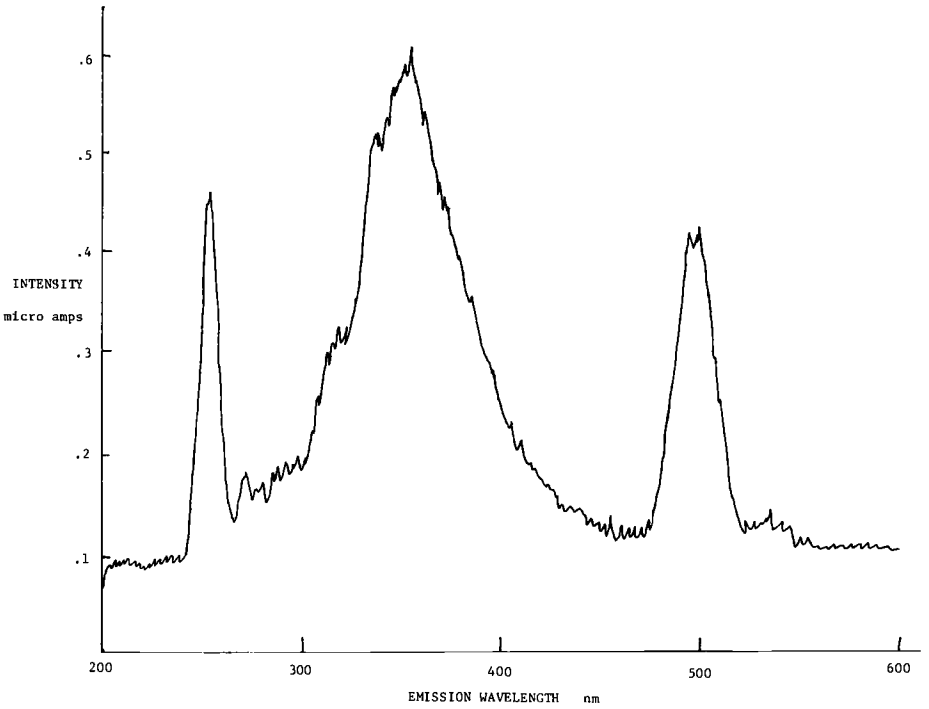

FIG. 5—*Sunoco Sunlube (SAE 30, Specimen 16, Group G). Room temperature single-wavelength spectrum at 255 nm plotted as microamperes versus emission wavelength.*

TABLE 3—*Further separation of the eight groups by using synchronous excitation fluorescence.*

Group	Subgroup	Number of Oils In Subgroup
A	A-1	2
B	B-1	3
C	C-1	1
	C-2	1
D	D-1	4
	D-2	5
E	E-1	1
	E-2	1
	E-3	2
	E-4	3
	E-5	5
F	F-1	1
	F-2	2
	F-3	3
G	G-1	11
	G-2	12
	G-3	1
	G-4	2
H	H-1	1

groups established by emission scans alone. The largest subgroups are from Group G, consisting of eleven and twelve specimens. Figure 6 is a synchronous excitation scan from one of the G subgroups.

Specimens from the Subgroups G-1 and G-2 (Table 3) were analyzed with the VSSE technique to determine if this method could further establish their uniqueness. The size of the initial separation and the angles that best distinguish oil specimens were determined. Six angles (50.2, 56.3, 59.0, 67.4, 76.0, and 84.3°) were arbitrarily chosen for all three test oil specimens, each of the six angles being used for all three specimens. A 20-nm initial separation was first used because it was known to be the optimum separation for the synchronous scans. By using a separation of 20 nm at 50.2° one of the specimens was shown to be different. Since two oils could not be distinguished, the instrumental conditions were varied. The three oils were run at all six angles with initial monochromator separations of 0, 10, 30, 40, and 50 nm. An initial separation of 0 nm can be used in this method, while it cannot be used in the synchronous excitation method, because the emission monochromator is scanning at a faster rate and in a short time will lead the excitation monochromator, thus preventing interference from Rayleigh scatter.

The 108 spectra obtained using the three oil specimens at the six different angles and six different monochromator separations were carefully compared to determine the conditions that best distinguished the three specimens.

The VSSE scan at 50.2° with an initial separation of 20 nm distinguished Specimen A from B and C, while an angle of 56.3° with an initial separation of 30 nm showed Specimen B to be different from Specimens A and C. Thus by using two scans at two different angles and separations, the three specimens were shown to be different. Upon further comparison

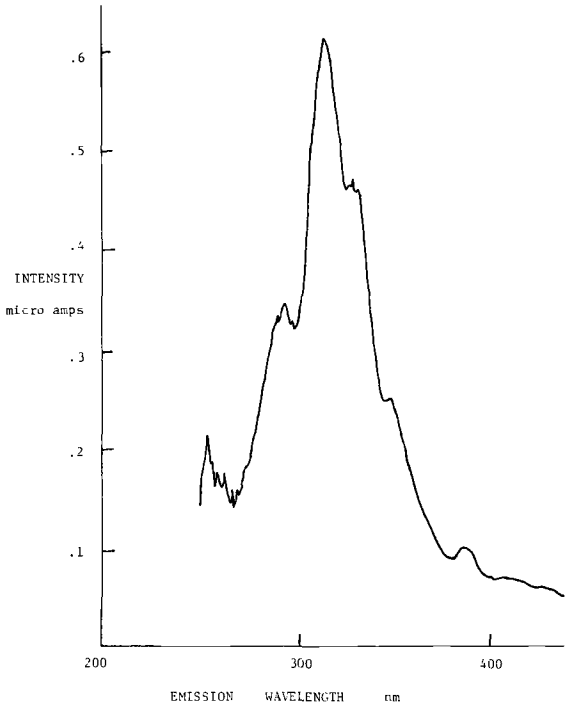

FIG. 6—*Pennzoil Racing Oil (SAE 30, Specimen 37, Subgroup G-1). Room temperature synchronous excitation at a separation of 20 nm plotted as microamperes versus emission wavelength.*

of the spectra, an angle of 59.0° with an initial separation of 30 nm and an angle of 67.4° with an initial separation of 40 nm also distinguished Specimen B from A and C. The spectra with an initial separation of 50 nm did not separate any of the specimens. The steep angles of 76.0 and 84.3° did not yield any useful information. As the separation between the excitation and emission wavelengths increases, a larger angle helps in distinguishing among specimens, suggesting that the topographical "hills" that distinguish the specimens are located as illustrated in Fig. 7. These data established that the four angles and separations given in Table 4 should be the most useful in attempting to differentiate the oil specimens contained in the two largest subgroups of Group G.

The 48 VSSE spectra from Subgroup G-1 and the 44 VSSE spectra from Subgroup G-2 were compared. Table 5 shows the results of the comparisons. Comparisons of the two separate groups were performed on the basis of the location of the relative heights and widths of the recorded peaks and shoulders. The specimens that were separated with 50.2° were placed into subgroups. The same procedure of sub-subgrouping was performed with the spectra obtained at 56.3, 59.0, and 67.4°. By reading Table 5 from left to right, the spectral information from the previous angle is expanded. For example, Specimen 38 cannot be separated from Specimens 36, 37, and 51 until the spectra at 67.4° are compared. This is depicted in Table 5 by Specimen 38 having an identification pattern of G-1 dio*r* and the other three specimens have an identification pattern of G-1 dio*s*. Similarly, Specimens 23 and 35 are shown to be different by comparison of the 59.0° spectra. Figures 8 and 9 show the different VSSE spectra at 59° for these two specimens. Specimen 23 has a classification of G-1 ch*m*s and Specimen 35 of G-1 ch*l*s. Even though most of the spectra are similar, all that is needed to distinguish among the specimens is a difference in the spectra run under any one condition.

Using VSSE fluorescence, the original group of 61 oils can be subdivided into groups having no more than three members in any group. It was assumed that since the largest subgroups (G-1 and G-2) could be further differentiated with VSSE, it would be possible for the other subgroups, which contain fewer specimens to be similarly individualized.

The 23 specimens in Subgroups G-1 and G-2 were frozen with liquid nitrogen and the single-wavelength excitation, synchronous excitation, and the four VSSE spectra were obtained. The same instrumental conditions employed at room temperature were maintained at liquid nitrogen temperatures. Figure 10 shows a liquid nitrogen synchronous excitation scan that was previously shown at room temperature. A sharpening of the spectral structure is observed in the low temperature scan when compared to the room temperature scan of the same specimen.

Table 6 depicts the specimens placed into six groups differentiated by the single wavelength excitation scan at liquid nitrogen temperature. Use of synchronous excitation at 77 K separates the 23 oils into two groups. Table 6 is read in the same manner as Table 5, and it is noted that by using liquid nitrogen temperature and fluorescence methods, the 23 specimens can be separated into groups with no more than two specimens in any group. By merging the information obtained by cryogenic and room temperatures, all specimens are differentiated except for 8 and 10. This is illustrated in Table 7. It is noted that Specimens 8 and 10 are of

TABLE 4—*Angles and separations for differentiating subgroups of Group G.*

Angle	Separation, nm
50.2°	20
56.3°	30
59.0°	30
67.4°	40

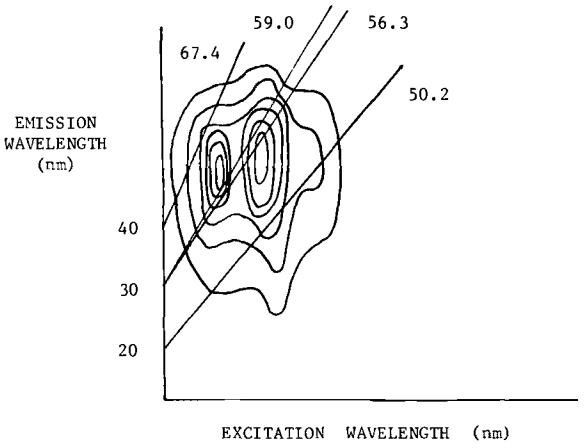

FIG. 7—*Three-dimensional contour plot showing the "cuts" of the four VSSE scans.*

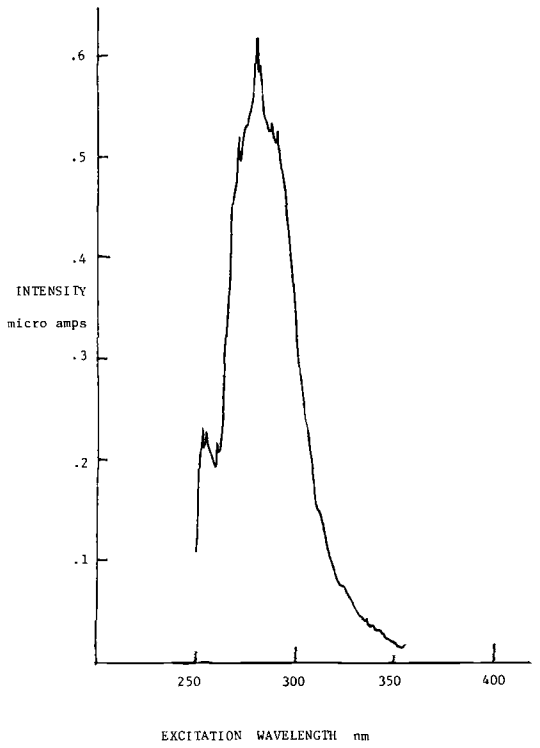

FIG. 8—*Shell X-100 (SAE 30, Specimen 23). Room temperature VSSE at 59.0° with 30-nm separation plotted as microamperes versus excitation wavelength.*

TABLE 5—*Room temperature classification.*[a]

Specimen	Normal Excitation Scan	Synchronous Scan	VSSE Scans 50.2°	56.3°	59.0°	67.4°	Numbers of Same Specimens
6	G	G-1	a	e	j	p	...
12	G	G-1	b	e	k	q	30
13	G	G-1	c	f	l	r	...
23	G	G-1	c	h	m	s	...
29	G	G-1	d	f	n	s	...
30	G	G-1	b	e	k	q	12
35	G	G-1	c	h	l	s	...
36	G	G-1	d	i	o	s	37,51
37	G	G-1	d	i	o	s	36,51
38	G	G-1	d	i	o	r	...
51	G	G-1	d	i	o	s	36,37
8	G	G-2	d	e	j	o	10
10	G	G-2	d	e	j	o	8
16	G	G-2	a	f	j	u	...
19	G	G-2	a	h	k	q	...
25	G	G-2	b	i	l	q	...
26	G	G-2	c	e	k	q	...
28	G	G-2	a	h	m	r	48
46	G	G-2	a	h	k	u	...
47	G	G-2	a	h	k	t	...
48	G	G-2	a	h	m	r	28
54	G	G-2	a	h	n	u	...
56	G	G-2	a	e	n	u	...

[a]Classification of the oil specimens in Group G with room temperature fluorescence. The table is read from left to right, each time adding another means of separation. A total classification with six possibilities is obtained and then compared.

TABLE 6—*Liquid nitrogen temperature classification.*[a]

Specimen	Normal Excitation Scan	Synchronous Scan	VSSE Scans 50.2°	56.3°	59.0°	67.4°	Numbers of Same Specimens
6	A-I	1	a	k	l	y	...
12	A-I	2	d	k	m	v	...
13	A-I	2	d	k	l	r	...
16	A-I	1	f	j	q	v	19
19	A-I	1	f	j	q	v	16
25	A-I	1	f	k	q	x	...
30	A-I	2	f	k	l	y	...
47	A-I	1	f	k	o	y	...
48	A-I	1	f	j	m	y	...
54	A-I	1	e	j	q	x	...
8	B-II	2	e	j	q	x	10
10	B-II	2	e	j	q	x	8
23	B-II	2	d	k	m	y	...
26	B-II	2	e	j	q	w	...
28	B-II	1	e	j	q	v	46
46	B-II	1	e	j	q	v	28
56	B-II	1	b	h	n	y	...
35	C-III	2	a	g	l	u	...
36	C-III	2	e	j	p	y	...
37	D-IV	2	c	j	q	s	...
38	E-V	2	e	j	q	t	...
51	E-V	2	f	j	m	t	...
28	F-VI	2	f	k	m	y	...

[a]Classification of the oil specimens previously in Group G with low temperature fluorescence. The table is read from left to right, each time adding another means of separation.

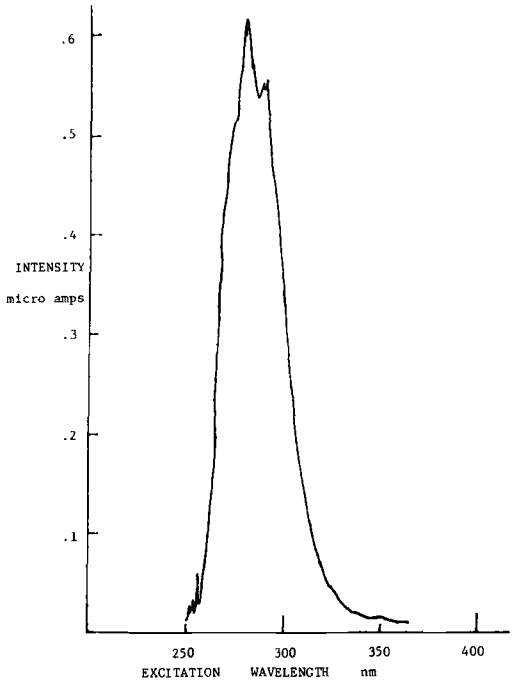

FIG. 9—*All Weather Multi-Grade (Specimen 35). Room temperature VSSE scan at 59.0° and 30-nm separation plotted as microamperes versus excitation wavelength.*

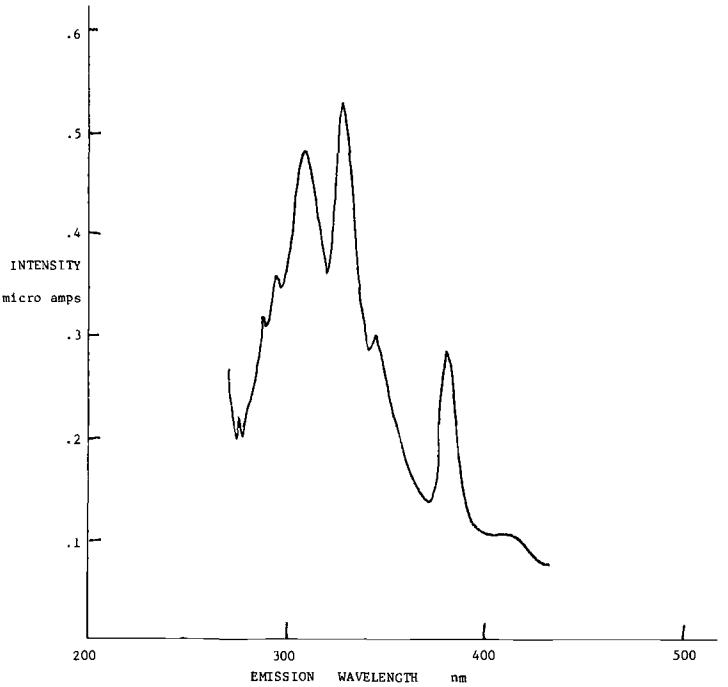

FIG. 10—*Pennzoil Racing Oil (SAE 30, Specimen 37). Cryogenic synchronous excitation at separation of 20 nm plotted as microamperes versus emission wavelength.*

TABLE 7—*Combined cryogenic and room temperature scans.*[a]

Specimens	Room Temperature						Liquid Nitrogen Temperature						Numbers of Same Oils
	Normal Scan	Synchron-Scan	VSSE Scans 50.2°	56.3°	59.0°	67.4°	Normal Scan	Synchrons Scan	VSSE Scans 50.2°	56.3°	59.0°	67.4°	
6	G	G-1	a	e	j	p	A-I	1	a	k	l	y	...
12	G	G-1	b	e	k	q	A-I	2	d	k	m	v	...
13	G	G-1	c	f	l	r	A-I	2	d	k	l	r	...
23	G	G-1	c	h	m	s	B-II	2	d	k	m	y	...
29	G	G-1	d	f	n	s	F-VI	2	f	k	m	y	...
30	G	G-1	b	e	k	q	A-I	2	f	k	l	y	...
35	G	G-1	c	h	l	s	C-III	2	a	g	l	u	...
36	G	G-1	d	i	o	s	C-III	2	e	j	p	y	...
37	G	G-1	d	i	o	s	D-IV	2	c	j	q	s	...
38	G	G-1	d	i	o	r	E-V	2	e	j	q	t	...
51	G	G-1	d	i	o	s	E-V	2	f	j	m	t	...
8	G	G-2	d	e	j	o	B-II	2	e	j	q	x	10
10	G	G-2	d	e	j	o	B-II	2	e	j	q	x	8
16	G	G-2	a	f	j	u	A-I	1	f	j	q	v	...
19	G	G-2	a	h	k	q	A-I	1	f	j	q	v	...
25	G	G-2	b	i	l	q	A-I	1	f	k	q	x	...
26	G	G-2	c	e	k	q	B-II	2	e	j	q	w	...
28	G	G-2	a	h	m	r	B-II	1	e	j	q	v	...
46	G	G-2	a	h	k	u	B-II	1	e	j	q	v	...
47	G	G-2	a	h	k	t	A-I	1	f	k	o	y	...
48	G	G-2	a	h	m	r	A-I	1	f	j	m	y	...
54	G	G-2	a	h	n	u	A-I	1	e	j	q	x	...
56	G	G-2	a	e	n	u	B-II	1	b	h	n	y	...

[a]**Classification of the oils specimens previously in Group G by compiling the information from room temperature and cryogenic fluorescence. The table is read from left to right, thus giving twelve means of classification.**

the same brand and weight, the difference being that 8 is a detergent oil; therefore, both may be practically identical in composition.

Conclusion

The use of variable separation synchronous excitation fluorescence has been shown to greatly increase oil individualization possibilities. This work is a preliminary study employing VSSE and traditional luminescence techniques for the identification of motor oils. Studies of used oils and other multicomponent systems have yet to be performed. However, the data presented suggest that continued applications of fluorescence analysis to the forensic science identification of automotive lubricants is worthy of future investigation.

Acknowledgments

The authors wish to acknowledge the cooperation of Samuel J. Rozzi, Commissioner of Police, County of Nassau, and the Commanding Officer of the Scientific Investigation Bureau, Captain Henry Hack, who graciously permitted the use of departmental facilities. The authors also wish to extend their appreciation to Drs. John Thornton, University of California-Berkely; R. E. Gaensslen, University of New Haven; and J. B. F. Lloyd of the Home Office Forensic Laboratory, Birmingham, England for their editorial comments pertaining to the original manuscript.

Mrs. Lasher performed much of this research in fulfillment of the American Chemical Society's requirement for undergraduate research towards her B.S. degree in Chemistry at C. W. Post College.

References

[1] Bentz, A. P., *Analytical Chemistry*, Vol. 48, No. 6, May 1976, p. 454.
[2] Gruenfeld, M. and Frank, U., "Prevention, Behavior, Control, Cleanup," Oil Spill Conference, May 1977.
[3] Frank, U., *1975 Conference on Prevention and Control of Oil Pollution*, San Francisco, March 1975.
[4] Lloyd, J. B. F., *Journal of the Forensic Science Society*, Vol. 11, 1971; No. 2, Part 1, pp. 83-94, No. 3, Part 2, pp. 153-170, No. 4, Part 3, pp. 235-253.
[5] Frank U. and Gruenfeld M., "Newsletter Analytical Quality Control," in *Selected Reprints Part I. Fluorescence Methods*, U.S. Environmental Protection Agency, 1977.
[6] Weiner, E. R., *Analytical Chemistry*, Vol. 50, No. 11, Sept. 1978, p. 1584.
[7] Freegarde, M., Hatchard, C. G., and Parker, C. A., *Lab Practice*, Vol. 20, No. 1, 1971, p. 35.
[8] Thruston, A. D. and Knight, R. W., *Environmental Science and Technology*, Vol. 5, No. 1, Jan. 1971, p. 64.
[9] Lloyd, J. B. F., *Journal of Forensic Sciences*, Vol. 25, No. 3, July 1980, pp. 589-602.
[10] Eastwood, D., Fortier, S. H., and Hendrick, *American Laboratory*, Vol. 10, No. 3, March 1978, p. 45.
[11] Eastwood, D. and Foertier, S. H., *Analytical Chemistry*, Vol. 50, No. 2, Feb. 1978, p. 334.

Address requests for reprints or additional information to
T. A. Kubic
Scientific Investigation Bureau
Nassau County Police Department
1490 Franklin Ave.
Mineola, NY 11501