Report of the Color Committee
May 15, 1946

Introduction

THE Color Committee is investigating the possibility of replacing the Lovibond system of measuring oil colors by a suitable photoelectric system that will be versatile, accurate, and acceptable to Industry and users in general. Work along this line has been divided into three logical steps:

1. Fairly complete investigation of several oils covering a wide range in color.
2. Correlation of data obtained on numerous oils in a limited color range with Lovibond colors, visual gradings, etc.
3. The use of a particular photoelectric setup to evaluate the bleach test on a single oil.

Work Done

Twelve samples of oil were carefully prepared by selection, filtration, etc., bottled in glass and submitted to several members of the Color Committee. The oils selected were:

Number 1	Refined and bleached coconut oil
2	Refined coconut oil
3	Refined and bleached cottonseed oil
4	Refined and bleached soybean oil
5	Refined cottonseed oil
6	Refined soybean oil
7-12	Tallow-grease mixtures

The Committee members were asked to read the Lovibond colors on the oils, and to read them on such photoelectric equipment as they had available, reporting the length of column read, the filters used, the kind of instrument, cell type, etc. Several members contributed data which is assembled in Tables 1, 2, 3, and 4. Both water and symmetrical tetrachlorethane were used as comparison media, the first for obvious reasons, the second because its refractive index is much nearer that of vegetable oils and to a certain extent will thereby eliminate negative readings.

Table No. 1 shows the Lovibond readings for the various oils. It should be noted that there is a considerable variation in readings even at low levels. Table No. 2 shows a composite of data obtained on the Klett-Summerson colorimeter, Cenco photolometer, Fisher electro-photometer, Coleman colorimeter, and Evelyn colorimeter. Table No. 3 shows more detailed information on the Coleman M-11 Universal spectrophotometer. Table No. 4 shows data on the Coleman and Evelyn colorimeters as well as these same data calculated to a basis of $E^{100\%}_{1cm.}$. No attempt should be made to compare E values obtained on one instrument directly with E values on the other, since different columns of oil have been used and different light characteristics. This will be discussed further later in the report. The data do represent one way of making comparisons after standardization of method is brought about.

Two laboratories contributed complete spectral transmission curves on all twelve oils as determined on the Beckman Model DU photoelectric spectrophotometer. A third laboratory contributed abbreviated curves in the region 400-600 mu. The transmission curves are plotted in Figure 1 while Table No. 5 shows the abbreviated data in tabular form. Transmissions are plotted on 100 mm. columns for oils 1 to 6, 25 mm. for 7 to 9, and 6.25 mm. for 10 to 12. Actually, the measurements were not made in all cases on these lengths of column, but where necessary the calculations have been made to place the oil on the indicated basis.

For the purposes of this study, the transmission curves on several of the filters used in the Klett-Summerson colorimeter were also determined on the Beckman spectrophotometer. The Klett-Summerson instrument utilizes a General Electric photocell No. 88x565. The spectral sensitivity of this cell is materially different from that of the eye, being essentially the same as the eye at maximum sensitivity (approximately 550 mu.) and through the red region of the spectrum, but being much more sensitive than the eye in the blue region. The combined response of photocell and filter combinations was calculated by multiplying the two response curves. The combined sensitivity curve was further modified by dividing each point on the curve by the maximum sensitivity of the filter-photocell combination. The resultant curves for filters 47, 50, 56, 60, and 66 are superimposed on the spectral transmission curves for the oils (Figure 1). These data represent available information and are not intended to imply that the Klett filters are preferable to other filters in any way. Similar comparisons can be drawn up for any filter-photocell combination.

The transmission curves in Figure 1 were plotted first to show a reasonable transmission, and secondly to give oil depths comparable to 40 mm., 10 mm., and

TABLE NO. 1

	Stillman		Milner		Agee		Durkee		Spannuth		Campbell		Corman		Average		Spread in Red	
	Y	R	Y	R	Y	R	Y	R	Y	R	Y	R	Y	R	Y	R	High	Low
1. RB Coconut Oil	2	0.4	2	0.3	2	0.7	2	0.5	2	0.2	2	0.4	3	0.8	2	0.5	0.8	0.2
2. Ref. Coconut Oil	4	1.2	5	1.1	6	1.3	5	1.4	5	1.4	5	1.2	6	1.4	5	1.3	1.4	1.1
3. RB Cottonseed Oil	8	1.4	10	1.2	9	1.7	8	1.4	8	1.4	7	1.4	12	1.2	9	1.4	1.7	1.2
4. RB Soybean Oil	10	2.0	15	1.5	23	2.0	18	2.0	20	2.0	15	2.0	25	2.1	18	1.9	2.1	1.5
5. Ref. Cottonseed Oil	20	4.2	20	3.7	35	4.3	30	4.4	40	4.2	25	4.1	35	4.6	29	4.2	4.6	3.7
6. Ref. Soybean Oil	30	7.7	53	9.7	35	8.8	35	7.9	50	8.9	35	7.7	35	8.8	39	8.5	9.7	7.7
7. Tallow-Grease Mix	110	15.4	70	13.7	35	12.9	70	14.4	....	....	75	14.2	100	15.0	77	14.3	15.4	12.9
8. Tallow-Grease Mix	50	24.1	70	25.9	35	25.3	70	23.0	....	....	70	23.3	70	25.0	61	24.4	25.9	23.0
9. Tallow-Grease Mix	120	31.7	70	31.0	35	32.0	170	37.0	....	....	90	31.6	100	32.0	98	32.6	37.0	31.0
10. Tallow-Grease Mix	240	11.2	70	4.5	35	8.7	280	11.0	65	6.8	90	7.3	65	13.0	121	8.9	13.0	4.5
11. Tallow-Grease Mix	140	17.3	70	17.4	35	15.4	150	21.0	75	15.0	70	14.1	100	17.7	91	16.8	21.0	14.1
12. Tallow-Grease Mix	210	47.3	....	....	35	50.0	250	53.0	120	50.0	70	37.2	105	18.0*	149	45.6	53.0	36.0

Oils 1 to 9 read on 5¼″ column, 10 to 12 read on 1″ column.
* Read on ½″ column, values doubled before using in the average.

TABLE NO. 2

Klett-Summerson Colorimeter Readings

	No. 47 Filter vs. H_2O			Col. Read.	Cal. to 40 mm.	No. 50 Filter vs. H_2O				Col. Read.	Cal. to 40 mm.	No. 56 Filter vs. H_2O			Col. Read.	Cal. to 40 mm.	No. 66 Filter vs. TCE*				Col. Read.	Cal. to 40 mm.
	GWA	RTM	Avg.			RCS	GWA	RTM	Avg.			RCS	RTM	Avg.			RCS	GWA	RTM	Avg.		
1. RB Coconut Oil	15.0	11.3	14.2	20 mm.	28.4	6.5	14.0	8.7	9.7	40 mm.	9.7	−2.8	−0.1	−1.5	40 mm.	−1.5	−1.0	....	5.9	2.5	40 mm.	2.5
2. Ref. Coconut Oil	24.3	24.8	24.6	20	49.2	22.1	33.6	24.8	26.8	40	26.8	4.0	8.9	6.5	40	6.5	1.0	3.4	9.0	4.5	40	4.5
3. RB Cottonseed Oil	27.3	26.2	26.8	20	53.6	23.5	24.0	22.8	23.4	40	23.4	−0.5	0.4	0.0	40	0.0	−1.5	....	3.0	0.8	40	0.8
4. RB Soybean Oil	64.3	60.8	62.6	20	125.2	52.2	45.8	47.0	48.3	40	48.3	1.5	1.2	1.4	40	1.4	−0.5	....	2.9	1.2	40	1.2
5. Ref. Cottonseed Oil	137	138	138	20	276	145	141	132	139	40	139	21.1	19.2	20.2	40	20.2	10.0	4.9	12.8	9.2	40	9.2
6. Ref. Soybean Oil	434	430	432	20	864	495	495	462	484	40	484	30.0	31.2	30.6	40	30.6	18.5	9.1	16.6	14.7	40	147
7. Tallow-Grease Mix	238	.240	239	10	956	289	295	271	285	20	570	156†	76.9	77.5	20	155	113	53	58.3	56	20	112
8. Tallow-Grease Mix	175	166	171	10	684	265	253	275	248	20	496	183†	85.3	88.4	20	177	57	20.3	25.2	25	20	50
9. Tallow-Grease Mix	251	240	246	10	984	370	378	331	360	20	720	132	120	126	20	252	76	53.8	55.0	62	20	122
10. Tallow-Grease Mix	257	280	269	2.5	4304	200	189	180	190	2.5	3340	266*	54.0	65.3	2.5	1045	266†	77.7	66.1	70	2.5	1120
11. Tallow-Grease Mix	218	219	219	2.5	3404	160	160	140	153	2.5	2448	60	58.2	59.1	2.5	946	40	33.0	28.0	34	2.5	544
12. Tallow-Grease Mix	......	315	315	2.5	5040	310	378	240	286	2.5	4576	130	117	124	2.5	984	70	59.0	52.8	61	2.5	976

Klett-Summerson readings by Stillman, Agee, and Milner.

†40 mm. column
*10 mm. column

†10 mm. column
*Tetrachlorethane

Readings on Various Colorimeters

	Cenco Photelometer-1 Filter-Trans.				Fisher Electro-Photometer—2 Filter-Trans.				Coleman Colorimeter—3 Filter-Trans.				Evelyn Colorimeter—4 Filter-Trans.							
	410	525	610	Cell Length	525 mu. 45 mm. cell	525	425	Cell Length	515	525	540	Cell Length	Against H_2O 515 A	Against H_2O 515 B	Against TCE 515 A	Against TCE 515 B	Against H_2O 540 A	Against H_2O 540 B	Against TCE 540 A	Against TCE 540 B
1. RB Coconut Oil	64.0	89.0	96.2	50	89.0	95.3	89.9	25	88.8	89.3	91.0	40	100+	....	92.3	94.8	100+	....	92.8	96.0
2. Ref. Coconut Oil	45.8	78.5	90.0	50	76.5	91.1	77.1	25	80.0	81.3	83.0	40	98.3	100	89.8	91.0	100+	....	91.8	93.3
3. RB Cottonseed Oil	34.8	88.0	100	50	87.0	93.7	67.5	25	85.0	88.3	91.5	40	100+	....	91.8	93.5	100+	....	94.5	93.5
4. RB Soybean Oil	15.5	85.0	100	50	81.5	91.2	43.7	25	78.3	83.8	89.0	40	98.3	98.5	90.0	90.5	100+	....	93.8	94.5
5. Ref. Cottonseed Oil	6.0	67.2	92.5	50	58.0	79.8	25.4	25	54.8	63.5	73.8	40	84.5	83.5	77.3	77.0	94	95.3	86.5	87.5
6. Ref. Soybean Oil	2.0	39.2	91.2	50	29.0	50.7	....	25	17.0	29.5	52.0	40	42.8	40.8	39.5	37.5	84.8	85.8	77.8	78.5
7. Tallow-Grease Mix	1.8	20.0	48.0	50	14.0	42.9	....	25	15.3	21.5	30.3	40	44.5	41.3	42.5	38.8	64.8	62.0	57.8	57.0
8. Tallow-Grease Mix	2.0	18.4	60.4	50	15.5	40.8	14.2*	25	14.3	18.8	25.8	40	42.5	43.0	39.0	39.5	56.5	58.5	52.3	54.0
9. Tallow-Grease Mix	8.8	58.0	81.0	10	....	27.7	....	25	7.5	10.0	15.0	40	31.0	30.0	28.8	27.3	45.3	47.3	41.8	43.8
10. Tallow-Grease Mix	1.8	13.0	22.0	10	....	....	....	10	2.0	2.5	4.0	20	2.3	1.5	2.5	1.0	4.0	4.8	5.3	4.3
11. Tallow-Grease Mix	1.8	16.0	39.0	10	....	10.3	....	10	2.3	3.0	5.0	20	3.0	2.0	3.0	1.8	6.0	6.5	6.8	5.8
12. Tallow-Grease Mix	1.5	5.0	25.0	10	....	....	....	10	0.5	0.5	1.0	20	0.3	0.0	0.8	0.0	0.8	0.3	1.0	0.0

*10mm. column

1—Results by M. N. States. 2—Results by Durkee & Potts. 3—Results by H. T. Spannuth. 4—Results by A—H. T. Spannuth, B—A. D. Campbell. Square cells were used throughout except on the Evelyn Colorimeter where 20 mm. round tubes were used.

TABLE NO. 4

A.O.C.S. Collaborative Color Samples 1 to 12

Oil No.	% Transmission										$E^{100\%}_{1\ cm.}$									
	Coleman Spectrophotometer No. 11						Evelyn Colorimeter				Coleman Spectrophotometer No. 11						Evelyn Colorimeter			
	515		525		540		515		540		515		525		540		515		540	
	H_2O	$EtCl_4$	H_2O	$EtCl_4$	H_2O	$EtCl_4$	H_2O	$EtCl_4$	H_2O	$EtCl_4$	H_2O	$EtCl_4$	H_2O	$EtCl_4$	H_2O	$EtCl_4$	H_2O	$EtCl_4$	H_2O	$EtCl_4$
1.	88.8	89.0	89.3	89.0	91.0	91.0	100+	92.3	100+	92.8	.01(3)	.01(3)	.01(2)	.01(3)	.01(0)	.01(0)	....	.01(7)	....	.01(6)
2.	80.0	80.0	81.3	81.5	83.0	84.0	98.3	89.8	100+	91.8	.02(4)	.02(4)	.02(2)	.02(2)	.02(0)	.01(9)	.00(4)	.02(3)	....	.01(9)
3.	85.0	86.0	88.3	88.5	91.5	91.5	100+	91.8	100+	94.5	.01(8)	.01(6)	.01(4)	.01(4)	.01(0)	.01(0)	....	.01(9)	....	.01(2)
4.	78.3	78.0	83.8	83.0	89.0	98.5	98.3	90.0	100+	93.8	.02(7)	.02(7)	.01(9)	.02(0)	.01(3)	.01(3)	.00(4)	.02(3)	....	.01(4)
5.	54.8	53.2	63.5	62.8	73.8	72.8	84.5	77.3	94.0	86.5	.06(5)	.06(7)	.04(8)	.05(1)	.03(4)	.03(4)	.03(7)	.05(6)	.01(3)	.03(2)
6.	17.0	16.5	29.5	27.8	52.0	50.0	42.8	39.5	84.8	77.8	.18(9)	.19(6)	.13(3)	.13(9)	.07(1)	.07(5)	.18(4)	.20(3)	.03(4)	.05(4)
7.	15.3	14.8	21.5	21.0	30.3	30.3	44.5	42.5	61.8	57.8	.20(4)	.20(7)	.16(7)	.16(9)	.13(0)	.13(0)	.17(6)	.18(5)	.10(5)	.11(9)
8.	14.3	14.0	18.8	18.0	25.8	25.3	42.5	39.0	56.5	52.3	.21(1)	.21(3)	.18(3)	.18(6)	.14(7)	.14(9)	.18(6)	.20(4)	.12(4)	.14(1)
9.	7.8	7.0	10.0	10.0	15.0	15.3	31.0	28.8	45.3	41.8	.27(8)	.28(9)	.25(0)	.25(0)	.20(6)	.20(4)	.25(4)	.27(0)	.17(2)	.18(9)
10.	2.0	2.0	2.5	2.8	4.0	4.0	2.3	2.5	4.0	5.3	.85(0)	.85(0)	.80(1)	.77(6)	.69(9)	.69(9)	.81(4)	.80(1)	.69(9)	.63(3)
11.	2.3	2.5	3.0	3.0	5.0	4.5	3.0	3.0	6.0	6.8	.82(4)	.80(1)	.76(1)	.76(1)	.65(1)	.67(3)	.76(1)	.76(1)	.61(1)	.58(4)
12.	0.5	0.5	0.5	0.75	1.0	1.0	0.3	0.8	0.8	1.0	1.1 (5)	1.1 (5)	1.1 (5)	1.0 (6)	1.00	1.00	1.2 (6)	1.0 (6)	1.04(5)	1.00

Notes:

1—On the Coleman instrument a 40 mm. cell was used for samples 1 to 9, and a 20 mm. cell for samples 10 to 12.
2—Cells used: Coleman—40 mm. and 20 mm. rectangular cells: Evelyn—20 mm. diameter test tubes.
3—Filters: Coleman—PC-4 range 400 to 700 mu.; Evelyn—"515" mu. range 485-550 mu., "540" mu. range 517-570 mu.
4—Oils 7 to 12 were heated 5° F. above their melting points.

TABLE NO. 3

A.O.C.S. Collaborative Color Samples 1 to 12

Percent Transmission—Coleman—13 mm. Column

Oil No.	400		425		450		500		525		550		610	
	H_2O	$EtCl_4$	H_2O	$EtCl_4$	H_2O	$EtCl_4$	H_2O	$EtCl_4$	H_2O	$EtCl_4$	H_2O	$EtCl_4$	H_2O	$EtCl_4$
1.	82.0	90.0	87.5	92.5	91.5	94.0	96.0	96.0	97.0	97.0	98.0	97.5	98.5	97.5
2.	77.5	85.5	84.0	89.0	88.5	91.5	95.2	95.0	97.0	96.7	98.0	97.5	99.5	98.3
3.	57.0	63.0	69.5	74.5	81.0	83.5	93.5	94.5	96.0	96.5	98.0	97.5	99.5	98.5
4.	34.5	38.0	46.5	50.0	62.0	65.0	88.0	88.7	94.5	94.5	97.5	97.5	99.7	99.3
5.	26.0	28.0	32.0	34.0	44.0	45.0	72.5	73.0	85.7	86.0	92.5	92.0	97.5	96.5
6.	6.5	8.0	5.5	6.0	6.0	6.0	15.0	16.0	52.0	53.5	86.0	83.0	87.2	95.0
7.	51.0	58.5	55.0	61.0	62.5	66.5	77.0	80.0	84.5	86.5	89.0	90.5	93.0	94.0
8.	58.0	67.0	69.5	76.0	79.0	86.0	91.0	94.5	95.0	97.0	97.0	99.0	99.5	100.0
9.	49.0	54.0	59.5	63.0	71.5	74.0	88.0	88.0	91.5	92.0	95.0	94.0	97.5	97.0
10.	20.0	26.5	22.5	29.0	38.0	45.5	70.5	77.0	79.0	82.0	84.0	86.0	88.0	88.5
11.	47.0	48.2	54.0	54.0	65.0	64.0	84.0	81.0	88.0	85.0	91.0	88.0	95.5	93.0
12.	16.0	17.0	20.0	21.0	32.0	33.5	50.0	62.0	69.0	70.0	75.5	76.5	85.5	86.0

Notes:
Instrument—Coleman M-11 Universal Spectrophotometer.
Wave length—In mu.
Filter—PC-4.
Cells—13 mm. square cuvettes.
Oils 1 to 6—Readings made on 100% oil; oils 7 to 12—10% oil in $EtCl_4$.

TABLE NO. 5

A.O.C.S Collaborative Color Samples 1-12. April 15, 1946.

Oil No.	Percent Transmission at Indicated Wave Lengths						
	400	420	450	500	520	560	610
1.	91.5	94.5	97.0	98.0	98.0	98.5	98.5
2.	86.5	90.0	93.0	96.5	97.0	98.0	99.0
3.	66.0	78.0	85.5	96.5	97.5	98.0	99.0
4.	33.5	51.0	71.0	92.5	96.0	99.0	99.5
5.	28.0	36.0	53.0	78.0	88.5	94.0	98.0
6. 10%	53.0	40.0	26.0	61.5	90.0	96.5	98.5
7. 10%	72.0	71.5	78.0	88.0	94.0	97.0	98.0
8. 10%	64.5	73.5	83.0	92.0	95.0	97.0	98.5
9. 10%	59.0	64.0	77.5	90.0	93.0	96.0	97.5
10. 10%	15.7	13.5	31.5	60.7	76.0	84.0	86.0
11. 10%	43.5	46.0	58.0	76.0	85.0	91.0	94.0
12. 10%	8.0	11.0	25.0	52.5	66.0	78.0	85.0

Notes:
1. Instrument—Beckman Quartz Spectrophotometer Model DU.
2. Blank—Ethylene Tetrachloride.
3. Cells—10 mm. cuvettes.
4. Concentrations
   1-5 inclusive read on pure oil;
   6-12, 10% oil solution in Ethylene Tetrachloride.
5. Wave length—in mu.

2.5 mm. column lengths which seem to be desirable in measuring the color of the oils on the Klett instrument. An inspection of Figure 1 shows:

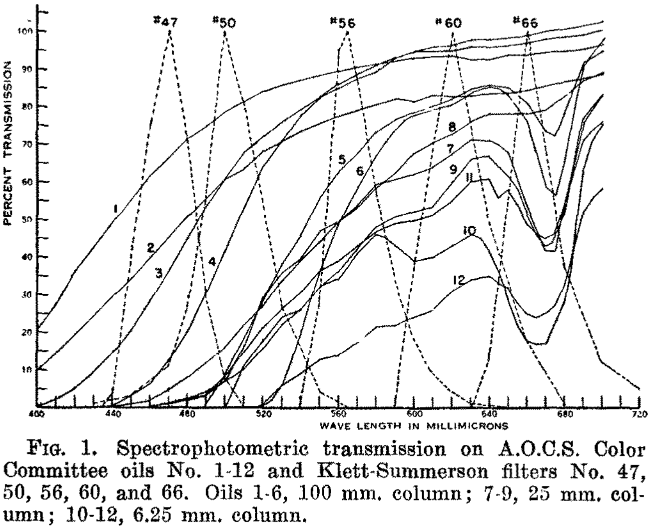


FIG. 1. Spectrophotometric transmission on A.O.C.S. Color Committee oils No. 1-12 and Klett-Summerson filters No. 47, 50, 56, 60, and 66. Oils 1-6, 100 mm. column; 7-9, 25 mm. column; 10-12, 6.25 mm. column.

1. That light colored oils show their greatest spread in transmission in the blue end of the spectrum (400 to 500 mu.). The darker oils show the widest spread in the red end (above 550 mu.).

2. If it is desirable to differentiate between light oils, a filter in the blue range, No. 47 for example, would be indicated. If dark oils only are to be closely separated, then a No. 56 or No. 60 filter is indicated. A filter near 500 mu. seems indicated if it is desirable to read all colors with a single filter.

3. The No. 66 filter is extremely useful in measuring chlorophyll absorption, especially when used in conjunction with the No. 60 filter.

Based on the conclusions derived above, from a study of oil transmissions and filter-photocell response curves, 89 oils were color analyzed by the Klett-Summerson colorimeter and the Lovibond colorimeter. These same oils were also placed in order by visual grading as to *color*. The oils were in two groups, Group 1 containing 37 oils and Group 2, 52 oils. These were all soybean and cottonseed oils. Some were refined and bleached, some refined only. Part were bleached in the plant, part in the laboratory.

Correlations were drawn up between Lovibond red readings and readings obtained on the Klett instrument using various filters. Figure 2 shows the correlation data sheet for Lovibond red vs. readings on the No. 50 filter. The correlation of 9395 is assurance that results obtained using a photocell instrument with the correct filter will give results differing not too greatly from the Lovibond. Calculation of *lines of best fit* for these oils show:

$$\text{Lovibond Red (R)} = 0.01335K + 1.20$$
$$\text{Klett Reading (K)} = 66.0R - 34.2$$

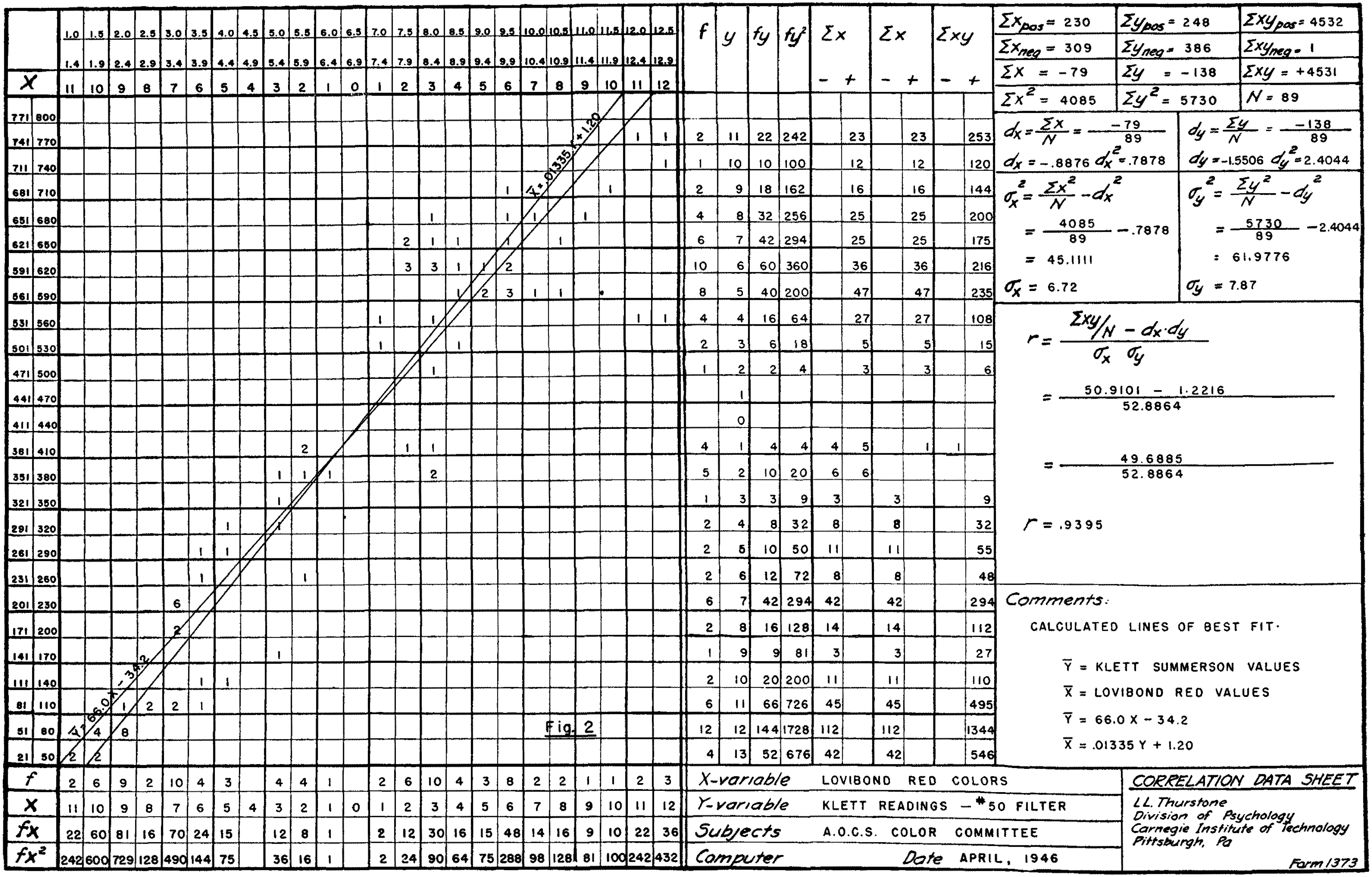
The correlation between Lovibond red readings and Klett readings, using the No. 47 filter and No. 56 filter, were much poorer.

No. 47 = .7496
No. 56 = .7774

Correlations making use of the Spearman-Brown rank order formula $\rho = 1 - \frac{6\Sigma d^2}{n(n^2-1)}$ were calculated for eye gradings vs. various filter readings and Lovibond readings.

Comparison	ρ	
	Group 1	Group 2
Eye vs. Lovibond red	.925	.958
Eye vs. No. 47 filter	.772	.852
Eye vs. No. 50 filter	.935	.959
Eye vs. No. 56 filter	.902	.936
Eye vs. No. 66 filter	.780	.908
Lovibond red vs. No. 50 filter	.855	.938

The interesting point in these correlations is the excellent agreement between eye gradings and readings obtained using the No. 50 filter. Equally as good is the correlation between the eye and Lovibond red readings.



		1.0 1.4	1.5 1.9	2.0 2.4	2.5 2.9	3.0 3.4	3.5 3.9	4.0 4.4	4.5 4.9	5.0 5.4	5.5 5.9	6.0 6.4	6.5 6.9	7.0 7.4	7.5 7.9	8.0 8.4	8.5 8.9	9.0 9.4	9.5 9.9	10.0 10.4	10.5 10.9	11.0 11.4	11.5 11.9	12.0 12.4	12.5 12.9	f	y	fy	fy^2	Σx		Σx		Σxy	
X		11	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10	11	12					−	+	−	+	−	+
771	800																																		
741	770																							1	1	2	11	22	242		23		23		253
711	740																								1	1	10	10	100		12		12		120
681	710																		1				1			2	9	18	162		16		16		144
651	680															1			1	1		1				4	8	32	256		25		25		200
621	650														2	1	1		1		1					6	7	42	294		25		25		175
591	620														3	3	1	1	2							10	6	60	360		36		36		216
561	590																1	2	3	1	1					8	5	40	200		47		47		235
531	560													1		1								1	1	4	4	16	64		27		27		108
501	530													1			1									2	3	6	18		5		5		15
471	500															1										1	2	2	4		3		3		6
441	470																										1								
411	440																										0								
381	410										2				1	1										4	1	4	4	4	5		1	1	
351	380									1	1	1				2										5	2	10	20	6	6				
321	350									1																1	3	3	9	3		3			9
291	320							1		1																2	4	8	32	8		8			32
261	290						1	1																		2	5	10	50	11		11			55
231	260						1				1															2	6	12	72	8		8			48
201	230					6																				6	7	42	294	42		42			294
171	200					2																				2	8	16	128	14		14			112
141	170									1																1	9	9	81	3		3			27
111	140						1	1																		2	10	20	200	11		11			110
81	110			1	2	2	1																			6	11	66	726	45		45			495
51	80		4	8																						12	12	144	1728	112		112			1344
21	50	2	2																							4	13	52	676	42		42			546
f		2	6	9	2	10	4	3		4	4	1		2	6	10	4	3	8	2	2	1	1	2	3										
X		11	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10	11	12										
fx		22	60	81	16	70	24	15		12	8	1		2	12	30	16	15	48	14	16	9	10	22	36										
fx^2		242	600	729	128	490	144	75		36	16	1		2	24	90	64	75	288	98	128	81	100	242	432										

$\Sigma x_{pos} = 230$	$\Sigma y_{pos} = 248$	$\Sigma xy_{pos} = 4532$
$\Sigma x_{neg} = 309$	$\Sigma y_{neg} = 386$	$\Sigma xy_{neg} = 1$
$\Sigma x = -79$	$\Sigma y = -138$	$\Sigma xy = +4531$
$\Sigma x^2 = 4085$	$\Sigma y^2 = 5730$	$N = 89$

$$d_x = \frac{\Sigma x}{N} = \frac{-79}{89}$$

$$d_x = -.8876 \quad d_x^2 = .7878$$

$$\sigma_x^2 = \frac{\Sigma x^2}{N} - d_x^2$$

$$= \frac{4085}{89} - .7878$$

$$= 45.1111$$

$$\sigma_x = 6.72$$

$$d_y = \frac{\Sigma y}{N} = \frac{-138}{89}$$

$$d_y = -1.5506 \quad d_y^2 = 2.4044$$

$$\sigma_y^2 = \frac{\Sigma y^2}{N} - d_y^2$$

$$= \frac{5730}{89} - 2.4044$$

$$= 61.9776$$

$$\sigma_y = 7.87$$

$$r = \frac{\Sigma xy/N - d_x \cdot d_y}{\sigma_x \quad \sigma_y}$$

$$= \frac{50.9101 - 1.2216}{52.8864}$$

$$= \frac{49.6885}{52.8864}$$

$$r = .9395$$

Comments:

CALCULATED LINES OF BEST FIT·

$\bar{Y}$ = KLETT SUMMERSON VALUES
$\bar{X}$ = LOVIBOND RED VALUES
$\bar{Y} = 66.0\,X - 34.2$
$\bar{X} = .01335\,Y + 1.20$

X-variable LOVIBOND RED COLORS
Y-variable KLETT READINGS — #50 FILTER
Subjects A.O.C.S. COLOR COMMITTEE
Computer Date APRIL, 1946

CORRELATION DATA SHEET

L.L. Thurstone
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Pittsburgh, Pa

Form 1373

FIG. 2.

Each member of the Refining Committee of the A.O.C.S. was asked to send a sample of refined and bleached oil No. 5 to one member of the Color Committee in order that a separate check on the overall color of the oil could be obtained. The Lovibond color on each oil and the readings on the Klett-Summerson colorimeter, using a No. 50 filter, were obtained on each oil as received. The data are reported in Table No. 6. Lovibond colors were calculated from the Klett readings using the equation shown in Figure 2. This equation, Lovibond red equals 0.01335 times the Klett reading, plus 1.2, gives results slightly high (approximately 0.3R) for low colors and slightly low (approximately 1.0R) for high colors. This does not mean that the equation is necessarily wrong for oils in general, but may merely indicate that the oil in question is not normal with respect to the oils used in determining the regression equation. The important point is not that calculated Lovibond red values do not exactly duplicate determined values, but that:

TABLE NO. 6

A.O.C.S Refined and Bleached Soybean Oil No. 5

Chem. No.	Lovibond Color Reported	Lovibond Color by Single Operator	Klett-Summerson Readings No. 50 Filter—40 cm. Cell		Lovibond Red Calculated from B
			A†	B†	
No. 49	20/1.9	20/1.5	......	49.5	1.86
No. 47	21/2.1	17/1.9	......	59.0	1.99
Southern Cotton Oil	20/1.8	16/1.6	......	55.2	1.94
Picard Testing Lab (1)	19/1.9	20/1.7	67.5	70.0	2.13
Picard Testing Lab (2)	19/1.8	20/1.8	59.5	61.5	2.02
Southwest Labs	20/1.6	17/1.6	47.0	51.0	1.88
No. 32	20/1.6	13/1.5	41.5	45.0	1.80
No. 59	18/1.4	10/1.3	45.5	49.0	1.85
No. 51	16/1.6	12/1.2	39.0	42.2	1.76
No. 3	16/1.6	20/1.8	72.5	77.0	2.23
Shuey & Company	19/1.9	20/1.8	60.0	64.0	2.05
No. 64	20/2.0	17/1.5	49.0	53.2	1.91
No. 46	27/2.6*	21/2.9	138.5	144.0	3.12
No. 24	22/1.8	16/1.9	69.2	74.3	2.19
F. R. Robertson	12/1.3	15/1.6	56.0	59.9	2.00
Edwal Labs (0.1)	20/2.0	20/1.8	75.5	79.8	2.27
Edwal Labs (0.2)	20/2.0	20/1.9	80.0	84.2	2.32
The Battle Lab	19/1.9	17/1.8	65.0	68.2	2.11
Fort Worth Lab	20/1.7	15/1.6	64.1	68.1	2.11
Pope Testing Lab	16/1.6	17/1.6	46.0	49.0	1.85
No. 44	18/1.7	18/1.7	55.0	59.1	1.99
R. B. Forbes	22/2.2	19/2.0	81.2	86.5	2.35
No. 75	20/1.0	15/1.5	......	45.0	1.80
Barrow-Agee	17/1.7	20/1.7	......	49.7	1.86
Average*	19–1.7	17–1.7	59.6	60.9	2.01
Maximum*	22–2.2	.20–2.0	81.2	86.5	2.35
Minimum*	12–1.0	12–1.2	39.0	42.2	1.76

Refined Oil A.O.C.S. No. 5

No. 47 (1)	....	35/10.5	......	620	9.5
No. 47 (2)	....	70/9.8	......	580	8.9
Barrow-Agee	....	35/10.4	......	585	9.0

† A & B are different No. 50 filters.

*Chem. No. 46 is excluded from all averages.

Δ Calculated from line of best fit Lovibond Red = 0.01335K+1.2 where K is the Klett reading with the No. 50 filter.

1. The photoelectric instrument will predict Lovibond values well within the limits of error of reading the colors by the Lovibond system;
2. The results determined photoelectrically show far less spread than determined Lovibond colors (spread 0.6 red vs. 1.2 red); and
3. A single operator is much more consistent than a number of operators in reading Lovibond colors.

Discussion

In any system of measuring oil colors, there are anomalies peculiar to that system. Certainly the practice of measuring the color of oils with Lovibond red only as the criterion and the practice of multiplying a 1″ column by a factor to convert to a 5¼″ column basis are peculiar to the Lovibond system. These anomalies are not of serious consequence if oils are examined in a specified manner, if specified conditions are adhered to by everyone making the comparisons, and if everyone recognizes that there are not only anomalies in the system, but in the oils as well. These anomalies make it almost impossible to convert mathematically color readings on one system to equivalent readings on another. In general, however, such a conversion is entirely unnecessary. Almost any system will work as long as it is sound basically and used intelligently.

It is frequently of interest, however, to compare different methods and attempt to evaluate their relative usefulness as an analytical tool. Correlations (see Figure 2) are useful in comparing methods especially over limited ranges, but when one attempts to evaluate two methods of doing the same thing, correlations between the methods are subject to the errors of each and are meaningless. How then can we evaluate the relative usefulness of the Lovibond system and a photoelectric filter system? This report does not present sufficient data to allow such a comparison, hence it will be well to look critically at only the photocell-filter method, reserving any critical comparison with the Lovibond system to a later date.

TABLE NO. 7

Various Gradings of Oils 1-12

Oil No.	Color Rank						
	Original Oils			10% Dilution in Oil No. 1			Standard* Shortening By Eye
	By Eye	By Lovibond	Klett No. 50	By Eye	By Lovibond	By Klett	
1.	1	1	1	1	1	1	1
2.	2	2	2	2	3½	2	2
3.	3	3	3	3	2	3	3
4.	4	4	4	4	3½	4	4
5.	5	5	5	5	5	5	5
6.	7	6	8	9	7½	9	8
7.	7	7	7	7	6	7	9
8.	7	8	6	6	7½	6	7
9.	9	9	9	8	9	8	6
10.	11	10	11	11	10	11	11
11.	10	11	10	10	11	10	10
12.	12	12	12	12	12	12	12

*Original oils stirred down with 20% hardstock.

In Table No. 7, several comparisons of the twelve oils are shown. In general, most any system places the first five oils in the same position. Oil No. 10 is misplaced by the Lovibond system because of its high green content. By eye there is but little difference between oils 6, 7, 8, and 9, the last (9) being slightly darker than the others. The Lovibond colors vary from 7.7 to 31.7 which is a very wide spread. The least that can be said from the data in Table No. 7 is the Klett readings using the No. 50 filter show very good agreement with visual observation whether the gradings are made on the original oils or on 10% dilutions in oil No. 1. In general, the Klett gradings are better than the Lovibond using the eye as the final criterion.

Oil No. 6 is a refined soybean oil which is very abnormal in its color reactions. This should be taken into consideration when making deductions concerning these oils. Some of the abnormalities appear thus,

Lovibond color 5¼″=20Y—7.6R
Lovibond color 1″ =20Y—3.0R
Klett-Summerson readings, No. 50 filter
40 mm. column = 495
20 mm. column = 370
10 mm. column = 279

Stirred down with 20% hardstock, No. 6 oil gave a buttery yellow product much more highly colored than oils 7, 8, and 9. In other words, the pigment in oil No. 6 intensifies greatly on dilution or on observation through a shortened column.

The use of any system of measuring oil colors is dependent upon a set of rules governing the conditions under which an oil shall be read. Such oils as No. 6, which will be placed in different positions depending upon the conditions of the test, make the specifications necessary. From the data so far obtained on the Klett-Summerson equipment, oils could be satisfactorily graded by specifying that any filter-photoelectric system may be used having a filter-photocell response comparable to that shown in Figure 1 for the No. 50 filter, that oils having an apparent color density up to 0.3 (300 on the Klett instrument) shall be read on a 40 mm. column, above 0.3 on a 40 mm. column shall be read on a 10 mm. column, and above 0.3 on a 10 mm. column shall be read on a 2.5 mm. column. Other conditions such as light source, temperature of oil, etc., should be specified.

Using the above conditions for length of column, the 12 oils were read on the Klett instrument using the No. 50, No. 56, No. 60, and No. 66 filter. The results are as follows:

Oil No.	No. 50	No. 56	No. 60	No. 66
1.	6.5	—2.8	—1.3	—5.5
2.	22.1	4.0	0.2	—3.5
3.	23.5	—0.5	—2.4	—6.1
4.	52.2	1.5	—1.9	—5.2
5.	145	21.1	4.2	5.5
6.	279	8.0	1.0	1.7
7.	155	44.3	30.0	33.2
8.	137	45.7	18.8	11.2
9.	189	65.8	34.5	32.4
10.	182	67.7	64.9	85.0
11.	160	60.0	31.1	40.0
12.	310	130	69.0	70.0

The use of a sufficiently higher refractive index blank than water would eliminate all of the negative values.

How do the readings on the Klett-Summerson instrument compare with readings on other instruments reported in Tables No. 2 and No. 3? Exact comparisons are impossible since exact comparisons necessarily demand that exact filter-photocell combinations be used. It appears however that any of the photoelectric instruments used in the study will do a good job of differentiating between the oils studied and any single instrument or combination could, therefore, probably be adopted for the purpose of grading oils.

Conclusions

The Committee feels that the work so far completed justifies the belief that a filter-photocell instrument, or a grating-photocell instrument can successfully be used to measure oil colors.

A filter (or grating setting) having a maximum transmission in the neighborhood of 500 mu. would probably be the most successful in differentiating between both dark and light oils. The possibility of using a filter-photocell combination having a response approximating normal visual sensitivity must not be overlooked.

The Committee hopes after a careful study of all the information so far obtained to continue the work on additional oils limiting the work to specific conditions that may later be adopted as accepted procedure.

No recommendations can be made at this time other than that the work of the Committee be continued.

Respectfully submitted,
G. Worthen Agee, Chairman,
Color Committee.

The Problem of "Fines" in Continuous Solvent Extraction Systems

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IF a check were made of the patent literature on the subject of continuous solvent extraction—literature very crowded, indeed—it would be surprising to discover how much attention has been given to continuous extractors and how little to the handling of the material itself before, during, and after extraction. Even in the matter of distillation of the miscella it apparently has been taken for granted that no solids exist in the liquid to be distilled, and all the attention has been given to the thermo-dynamics.

The main advantage of the continuous system over the old batch systems is the steady flow of the material under process, and its outstanding feature is the high degree of safety derived from the fact that the material flows throw vapor-tight apparatus, pipes, and conveyors without the necessity of periodical interruptions or manual intervention.

The continuity of the flow, however, is frequently and often unexpectedly interrupted by the presence of "fines" and dust in the system when the equipment is unable to cope with it. Instead of trying to solve the problem radically, only temporary remedies have been adopted so far as, for example, using auxiliary equipment such as filter presses in the miscella cycle or elaborate dust collectors in the vapor lines to protect condensers—both devices more or less originally designed for entirely different operating conditions.

A rational solution of the problem would be to first attempt to avoid the production of "fines" as far as possible during the several steps of the process and then to design adequate equipment to handle them without trouble.

Only a long experience in operating continuous solvent extraction plants will give an idea of how such a simple process is complicated by seemingly