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SIXTEEN samples of linseed oil of known origin and purity were tested. A complete history of these samples is given in Technologic Paper No. 9, Bureau of Standards, and also in the 1911 *Proceedings of the American Society for Testing Materials*. Six samples of gum turpentine, three samples of wood turpentine, two samples of "wood spirits," and one sample of "oil" of turpentine were also tested.

The density of each sample was determined at 10°, 20°, 30°, and 40° C. by the method of hydrostatic weighing. Special apparatus was employed by means of which any turpentine between 10° and 40° C. could be obtained and automatically maintained sensibly constant for any desired length of time. The densities were determined by weighing in the sample at each temperature a plummet or sinker of known mass and volume, the sinker having been calibrated by weighing in twice-distilled water.

The temperatures were read on two mercurial thermometers suspended in a glass tube placed parallel and adjacent to the tube containing the sample.

The sinker used in the density determinations was of Jena 16^{III} glass, ballasted with mercury, and had approximately the following dimensions: length, 30 cm.; diameter, 15 cm.; volume, 50 c.c.; mass, 190 g.

In making a density determination the method of procedure was as follows: The water in the outside bath was brought to the desired temperature by proper adjustment of the heating and cooling coils. After sufficient time had elapsed to allow the apparatus to attain temperature equilibrium, observations were begun. First, a weighing was made with the sinker suspended in the liquid, then the two thermometers were read; next, a tare weighing was made with the suspension wire still passing through the surface of the liquid, but with the sinker detached and resting on the bottom of the containing tube; then a second weighing with the sinker attached, and after that a second reading of the thermometers.

After completing the observations on a sample at the four temperatures 10° , 20° , 30° , and 40° C., the density at each temperature was calculated by means of the equation

$$D_t = \frac{W - \frac{(w-w_1) + (w-w_2)}{2} \left(1 - \frac{\rho}{8.4}\right)}{V_t}$$

In which D_t = density of sample at temp. t . (in gms/ml).

W = weight of sinker in vacuo.

w = weighing with sinker off.

w_1 and w_2 = weighing with sinker on.

ρ = air density.

8.4 = assumed density of brass weights.

V_t = volume of sinker at temp. t .

After calculating the density at each temperature, a least squares reduction was applied to the calculated results in order to find the most probable value of the density at each temperature. It was assumed that the equation $D_t = D + \alpha(t - x) + \beta(t - x)^2$ represents sufficiently well the rate of expansion. The very small residuals obtained show that the assumption was justified.

A summary of the results of the investigation is here given.

SUMMARY OF RESULTS

TABLE I

THE DENSITY AND THERMAL EXPANSION OF LINSEED OIL AT TEMPERATURES BETWEEN 10° AND 40° C.

Sample No.	$D_{4^{\circ}C}^{10^{\circ}C}$	$D_{4^{\circ}C}^{20^{\circ}C}$	$D_{4^{\circ}C}^{30^{\circ}C}$	$D_{4^{\circ}C}^{40^{\circ}C}$	$D_{4^{\circ}C}^{25^{\circ}C}$	$\alpha \times 10^7$	$\beta \times 10^9$
5.....	.93 513	.92 823	.92 139	.91 460	.92 480	-6844	+262
16.....	.93 526	.92 841	.92 158	.91 475	.92 499	-6836	+ 50
13.....	.93 561	.92 875	.92 193	.91 514	.92 534	-6823	+192
2.....	.93 598	.92 911	.92 226	.91 543	.92 568	-6851	+ 90
11.....	.93 606	.92 920	.92 235	.91 552	.92 578	-6848	+ 58
3.....	.93 614	.92 928	.92 244	.91 561	.92 586	-6843	+ 90
12.....	.93 624	.92 938	.92 255	.91 573	.92 596	-6838	+ 95
6.....	.93 668	.92 981	.92 295	.91 611	.92 638	-6857	+110
14.....	.93 704	.93 016	.92 329	.91 642	.92 672	-6875	+ 38
8.....	.93 710	.93 022	.92 338	.91 657	.92 680	-6843	+168
7.....	.93 716	.93 031	.92 347	.91 664	.92 688	-6840	+ 78
4.....	.93 738	.93 049	.92 365	.91 686	.92 706	-6842	+240
9.....	.93 746	.93 062	.92 377	.91 691	.92 720	-6850	- 88
15.....	.93 755	.93 063	.92 378	.91 699	.92 720	-6852	+320
10.....	.93 761	.93 073	.92 389	.91 707	.92 730	-6844	+155
1.....	.93 789	.93 100	.92 413	.91 727	.92 756	-6873	+ 78
Mean..					92 634	-6847	+120

$$(1) \quad D_t = D_{25} + \alpha (t-25) + \beta (t-25)^2$$

Taking for α and β the mean values of the 16 samples the general equation becomes $D_t = D_{25} - 0.000\ 6847(t-25) + 0.000\ 000\ 12(t-25)^2$. If it is desired to reduce the expansion to a single term for use over a short temperature range, this may be done by differentiating the general equation and combining α and β into a single term, α^1 , which will be different for different temperatures.

$$(2) \quad \begin{aligned} D_t &= D_{25} + \alpha (t-25) + \beta (t-25)^2 \\ \frac{dD_t}{dt} &= \alpha + 2\beta(t-25) = \alpha^1 \end{aligned}$$

Substituting for t the values 10, 15, 20, 25, 30, 35, and 40, gives for the rate of change of density at the different temperatures the following values:

Temperature. ° C.	Change per degree C.
10	0.000 688 3
15	.000 687 1
20	.000 685 9
25	.000 684 7
30	.000 683 5
35	.000 682 3
40	.000 681 1

The results obtained from the six samples of gum turpentine shown in Group I were used in the calculation of Table IV for determining the density of turpentine at various temperatures.

If the general equation $D_t = D_{25} + \alpha (t-25) + \beta (t-25)^2$ be differentiated and the mean values of α and β substituted in the first derivative the change of density per degree at different temperatures is seen to be as shown below.

$D_t = D_{25} + \alpha (t-25) + \beta (t-25)^2$	
$\frac{dD_t}{dt} = \alpha + 2\beta (t-25) = \text{change of density per degree} = \alpha^1$	
t	α^1
10	.000 814 2
15	815 1
20	816 1
25	817 0
30	817 9
35	818 9
40	819 8

In calculating Table IV these values of α^1 were taken as the rate of change of density of turpentine having a density of 0.8640 at 20° C. (this being the mean of the six samples from

TABLE II
DENSITY AND THERMAL EXPANSION OF TURPENTINE AT TEMPERATURES BETWEEN 10° AND 40° C.

Sample No.	$D_{4}^{10^{\circ}}$	$D_{4}^{20^{\circ}}$	$D_{4}^{30^{\circ}}$	$D_{4}^{40^{\circ}}$	$D_{4}^{25^{\circ}}$	$a \times 10^7$	$\beta \times 10^9$	Refractive index at 27° C.	Optical rotation at 25° C.	Remarks.
3.....	.86 932	.86 124	.85 314	.84 500	.85 719	-8104	-150	1.4671	- 8.6	Group I, gum turpentine.
7.....	.86 988	.86 174	.85 357	.84 539	.85 766	-8165	- 95	1.4673	+15.9	
2.....	.87 211	.86 394	.85 574	.84 752	.85 984	-8195	-105	1.4710	- 7.2	
8.....	.87 256	.86 440	.85 623	.84 804	.86 032	-8174	- 55	1.4670	+12.7	
12.....	.87 393	.86 576	.85 756	.84 933	.86 166	-8198	-148	1.4672	+ 4.3	
1.....	.87 468	.86 649	.85 831	.85 012	.86 240	-8186	- 8	1.4784	+14.4	Group II, wood turpentine steam distilled.
Mean.....						-8170	- 94			
9.....	.86 988	.86 165	.85 341	.84 516	.85 753	-8242	- 55	1.4636	+22.9	
10.....	.87 024	.86 205	.85 384	.84 559	.85 795	-8214	-160	1.4656	+17.7	
4.....	.87 229	.86 406	.85 571	.84 724	.85 990	-8350	-580	1.4648	+26.3	
Mean.....						-8269	-265			Group III, wood "spirits" destructively distilled.
5.....	.87 380	.86 456	.85 547	.84 626	.86 006	-9181	-130	1.4594	+ 4.7	
6.....	.87 606	.86 693	.85 775	.84 852	.86 235	-9181	-258	1.4613	+ 4.7	
11.....	.95 518	.94 728	.93 930	.93 123	.94 330	-7986	-428	1.4789	0.0	

which α^1 was derived). For turpentine having a density at 20° either greater or less than $0.8640 \alpha^1$ was calculated from mean $D \frac{20^\circ}{4^\circ}$ and mean α^1 of the three lightest samples and mean $\frac{D_{20^\circ}}{4^\circ}$ and mean α^1 of the three heaviest samples.

TABLE III

DENSITY OF LINSEED OIL AT ANY TEMPERATURE BETWEEN 10° AND 40° C. FROM ITS DENSITY AT 20° C.

	Density at 20° C. (in grams per milliliter).						
	0.9260	0.9270	0.9280	0.9290	0.9300	0.9310	0.9320
Required temperature.	Density at required temperature.						
$^\circ$ C.							
10	0.9329	0.9339	0.9349	0.9359	0.9369	0.9379	0.9389
11	.9322	.9332	.9342	.9352	.9362	.9372	.9382
12	.9315	.9325	.9335	.9345	.9355	.9365	.9375
13	.9308	.9318	.9328	.9338	.9348	.9358	.9368
14	.9301	.9311	.9321	.9331	.9341	.9351	.9361
15	.9294	.9304	.9314	.9324	.9334	.9344	.9354
16	.9288	.9298	.9308	.9318	.9328	.9338	.9348
17	.9281	.9291	.9301	.9311	.9321	.9331	.9341
18	.9274	.9284	.9294	.9304	.9314	.9324	.9334
19	.9267	.9277	.9287	.9297	.9307	.9317	.9327
20	.9260	.9270	.9280	.9290	.9300	.9310	.9320
21	.9253	.9263	.9273	.9283	.9293	.9303	.9313
22	.9246	.9256	.9266	.9276	.9286	.9296	.9306
23	.9239	.9249	.9259	.9269	.9279	.9289	.9299
24	.9233	.9243	.9253	.9263	.9273	.9283	.9293
25	.9226	.9236	.9246	.9256	.9266	.9276	.9286
26	.9219	.9229	.9239	.9249	.9259	.9269	.9279
27	.9212	.9222	.9232	.9243	.9252	.9262	.9272
28	.9205	.9215	.9225	.9235	.9245	.9255	.9265
29	.9198	.9208	.9218	.9228	.9238	.9248	.9258
30	.9192	.9202	.9212	.9222	.9232	.9242	.9252
31	.9185	.9195	.9205	.9215	.9225	.9235	.9245
32	.9178	.9188	.9198	.9208	.9218	.9228	.9238
33	.9171	.9181	.9191	.9201	.9211	.9221	.9231
34	.9164	.9174	.9184	.9194	.9204	.9214	.9224
35	.9157	.9167	.9177	.9187	.9197	.9207	.9217
36	.9150	.9160	.9170	.9180	.9190	.9200	.9210
37	.9144	.9154	.9164	.9174	.9184	.9194	.9204
38	.9137	.9147	.9157	.9167	.9177	.9187	.9197
39	.9130	.9140	.9150	.9160	.9170	.9180	.9190
40	.9123	.9133	.9143	.9153	.9163	.9173	.9183

TABLE IV
DENSITY OF TURPENTINE AT ANY TEMPERATURE BETWEEN 10° AND 40° C. FROM ITS DENSITY AT 20° C.

Required temperature °C	Density at 20° C. (in grams per milliliter).										Density at required temperature.									
	0.8550	0.8560	0.8570	0.8580	0.8590	0.8600	0.8610	0.8620	0.8630	0.8640	0.8650	0.8660	0.8670	0.8680	0.8690	0.8700				
	0.8550	0.8641	0.8651	0.8661	0.8671	0.8681	0.8691	0.8701	0.8711	0.8722	0.8732	0.8742	0.8752	0.8762	0.8772	0.8782				
10	0.8631	0.8641	0.8651	0.8661	0.8671	0.8681	0.8691	0.8701	0.8711	0.8722	0.8732	0.8742	0.8752	0.8762	0.8772	0.8782				
11	0.8623	0.8633	0.8643	0.8653	0.8663	0.8673	0.8683	0.8693	0.8703	0.8713	0.8724	0.8734	0.8744	0.8754	0.8764	0.8774				
12	0.8614	0.8625	0.8635	0.8645	0.8655	0.8665	0.8675	0.8685	0.8695	0.8705	0.8715	0.8725	0.8735	0.8746	0.8756	0.8766				
13	0.8606	0.8616	0.8627	0.8637	0.8647	0.8657	0.8667	0.8677	0.8687	0.8697	0.8707	0.8717	0.8727	0.8737	0.8747	0.8758				
14	0.8598	0.8608	0.8618	0.8629	0.8639	0.8649	0.8659	0.8669	0.8679	0.8689	0.8699	0.8709	0.8719	0.8729	0.8739	0.8749				
15	0.8590	0.8600	0.8610	0.8620	0.8630	0.8641	0.8651	0.8661	0.8671	0.8681	0.8691	0.8701	0.8711	0.8721	0.8731	0.8741				
16	0.8582	0.8592	0.8602	0.8612	0.8622	0.8632	0.8642	0.8652	0.8663	0.8673	0.8683	0.8693	0.8703	0.8713	0.8723	0.8733				
17	0.8574	0.8584	0.8594	0.8604	0.8614	0.8624	0.8634	0.8644	0.8654	0.8664	0.8674	0.8684	0.8695	0.8705	0.8715	0.8725				
18	0.8566	0.8576	0.8586	0.8596	0.8606	0.8616	0.8626	0.8636	0.8646	0.8656	0.8666	0.8676	0.8686	0.8696	0.8706	0.8716				
19	0.8558	0.8568	0.8578	0.8588	0.8598	0.8608	0.8618	0.8628	0.8638	0.8648	0.8658	0.8668	0.8678	0.8688	0.8698	0.8708				
20	0.8550	0.8560	0.8570	0.8580	0.8590	0.8600	0.8610	0.8620	0.8630	0.8640	0.8650	0.8660	0.8670	0.8680	0.8690	0.8700				
21	0.8542	0.8552	0.8562	0.8572	0.8582	0.8592	0.8602	0.8612	0.8622	0.8632	0.8642	0.8652	0.8662	0.8672	0.8682	0.8692				
22	0.8534	0.8544	0.8554	0.8564	0.8574	0.8584	0.8594	0.8604	0.8614	0.8624	0.8634	0.8644	0.8654	0.8664	0.8674	0.8684				
23	0.8526	0.8536	0.8546	0.8556	0.8566	0.8576	0.8586	0.8596	0.8606	0.8616	0.8626	0.8636	0.8645	0.8655	0.8665	0.8675				
24	0.8518	0.8528	0.8538	0.8548	0.8558	0.8568	0.8578	0.8587	0.8597	0.8607	0.8617	0.8627	0.8637	0.8647	0.8657	0.8667				
25	0.8510	0.8520	0.8530	0.8540	0.8549	0.8559	0.8569	0.8579	0.8589	0.8599	0.8609	0.8619	0.8629	0.8639	0.8649	0.8659				
26	0.8502	0.8512	0.8521	0.8531	0.8541	0.8551	0.8561	0.8571	0.8581	0.8591	0.8601	0.8611	0.8621	0.8631	0.8641	0.8651				
27	0.8493	0.8503	0.8513	0.8523	0.8533	0.8543	0.8553	0.8563	0.8573	0.8583	0.8593	0.8603	0.8613	0.8623	0.8632	0.8642				
28	0.8485	0.8495	0.8505	0.8515	0.8525	0.8535	0.8545	0.8555	0.8565	0.8575	0.8585	0.8594	0.8604	0.8614	0.8624	0.8634				
29	0.8477	0.8487	0.8497	0.8507	0.8517	0.8527	0.8537	0.8547	0.8557	0.8566	0.8576	0.8586	0.8596	0.8606	0.8616	0.8626				
30	0.8469	0.8479	0.8489	0.8499	0.8509	0.8519	0.8529	0.8538	0.8548	0.8558	0.8568	0.8578	0.8588	0.8598	0.8608	0.8618				
31	0.8461	0.8471	0.8481	0.8491	0.8501	0.8510	0.8520	0.8530	0.8540	0.8550	0.8560	0.8570	0.8580	0.8590	0.8600	0.8610				
32	0.8453	0.8463	0.8473	0.8483	0.8492	0.8502	0.8512	0.8522	0.8532	0.8542	0.8552	0.8562	0.8572	0.8582	0.8591	0.8601				
33	0.8445	0.8455	0.8465	0.8474	0.8484	0.8494	0.8504	0.8514	0.8524	0.8534	0.8544	0.8554	0.8563	0.8573	0.8583	0.8593				
34	0.8437	0.8447	0.8456	0.8466	0.8476	0.8486	0.8496	0.8506	0.8516	0.8526	0.8535	0.8545	0.8555	0.8565	0.8575	0.8585				
35	0.8429	0.8438	0.8448	0.8458	0.8468	0.8478	0.8488	0.8498	0.8508	0.8517	0.8527	0.8537	0.8547	0.8557	0.8567	0.8576				
36	0.8421	0.8430	0.8440	0.8450	0.8460	0.8470	0.8480	0.8490	0.8499	0.8509	0.8519	0.8529	0.8539	0.8549	0.8558	0.8568				
37	0.8412	0.8422	0.8432	0.8442	0.8452	0.8462	0.8472	0.8481	0.8491	0.8501	0.8511	0.8521	0.8530	0.8540	0.8550	0.8560				
38	0.8404	0.8414	0.8424	0.8434	0.8444	0.8454	0.8463	0.8473	0.8483	0.8493	0.8503	0.8512	0.8522	0.8532	0.8542	0.8552				
39	0.8396	0.8406	0.8416	0.8426	0.8435	0.8445	0.8455	0.8465	0.8475	0.8485	0.8494	0.8504	0.8514	0.8524	0.8534	0.8544				
40	0.8388	0.8398	0.8408	0.8418	0.8427	0.8437	0.8447	0.8457	0.8467	0.8476	0.8486	0.8496	0.8506	0.8516	0.8526	0.8535				