LETTER REPORT

FRICTION AND THERMAL IMAGING OF TREATED BEARING MATERIALS

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Friction and Thermal Imaging of Treated Bearing Materials

WFO for BTN, Chattanooga, TN

1. BACKGROUND

BETTER THAN NEW (BTN) has developed a proprietary process to apply a friction-reducing treatment to a variety of friction and wear-critical parts including tooling and engine components. Evidence obtained from field trials indicate the lubricity of this material, but systematic laboratory friction and wear data were not readily available. ORNL was approached by BTN to verify the performance of its treatment on a pair of common bearing steels under controlled conditions.

2. PURPOSE/OBJECTIVE

The purpose of this work was to determine friction coefficients of a proprietary treatment under sliding wear conditions when the treatment is used on one or both surfaces of an alloy steel couple, and compare the results to non-treated steel tested under the same conditions. In addition, an infrared camera was used in an attempt to detect differences in frictional heating due to sliding with and without the treatment.

3. TEST MATRIX and MATERIALS

ORNL obtained alloy steels and machined them to fit ORNL's Variable Load Bearing Tester (VLBT) which was designed to simulate variable loads and contact pressures as might be experienced by an internal combustion engine component during operation. After machining in a condition typical of engine applications, BTN applied a friction-reducing treatment to certain test specimens in order to investigate the following combinations of sliding conditions:

Contact geometry:	flat plate pressed upward against a rotating cylindrical shaft.
Step-loading single cycle:	20, 30, 40, 50, 40, 30 N per cycle
Time for each load step in the cycle:	10 s
Cycles of loading per experiment:	5
Total sliding distance per experiment:	30 m
Sliding speed:	0.1 m/s
Repeats:	Caution: It is recognized that with only one test per combination, the repeatability of these results cannot be established.
Specimen Materials:	The form and composition of the steels used as sliding partners is shown in Table 1.

Item or Parameter	8620 Steel	4142 Steel
Source	McMaster Carr	McMaster Carr
Form	1.00" diameter precision rod	1.00 wide x 0.25 thick, pre-hardened
		precision ground flat stock
Test specimen	1.00" OD x 3.0" long rods (rotating	1.00 x 1.00 x 0.25" coupons
	specimen)	(fixed specimen)
Composition (wt %)		
С	0.18 - 0.23	0.38 - 0.46
Mn	0.7 – 0.9	0.7 - 1.0
Si	0.20 - 0.35	0.15 - 0.30
Р	0.04 max	0.035 max
S	0.04 max	0.040 max
Cr	0.4 - 0.6	0.8 - 1.15
Мо	0.15 – 0.25	0.15 - 0.25
V	-	0.03 max
Ni	0.4 – 0.7	-

Table 1. Form and Composition of Test Materials Used in this	Project (continued on next page)
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Surface finish and list of runs. Measurements of the as-received cylinders and flat specimens indicated arithmetic average roughness (Ra) and ten-point height (Rz) are given in Table 2. The runs conducted using the specimens provided without further treatment or cleaning, are listed in Table 3. All runs produced data on normal force, friction force, and temperature (by IR camera measurements).

Table 2. Surface Roughness of As-Received, Non-coated Specimens

Specimen	Ra (µm)	Rz (μm)
Cylinder (non-coated)	0.028	0.20
Flat (non-coated)	0.048	0.49

Table 3. Test Runs, Treatments*, and Run Numbers

Run number	Cylinder Specimen	Flat Specimen
VLBT-60	Not treated	Not treated
VLBT-61	Treated	Treated
VLBT-63	Treated	Not treated

4. **RESULTS**

4.1 Friction Results.

Self-mated tests. Figure 1 shows the load spectrum and the corresponding friction coefficients for the first cycle for run number VLBT 60, and Figure 2 shows the last cycle of the same test. In comparison, Figure

3 shows the first cycle of test VLBT-61 (both cylinder and flat specimen treated) and Figure 4 the last cycle of the same test. Clearly, the treated pair was less sensitive to changes in normal force.

Figure 4 shows the friction versus testing time behavior for last cycle of the non-treated couple, the treated-on-treated couple, and the treated rod on non-treated flat specimen couple. Clearly, the non-treated steel surfaces had much higher friction coefficient than the treated ones, and the couple with both sides treated performed the best of all three.

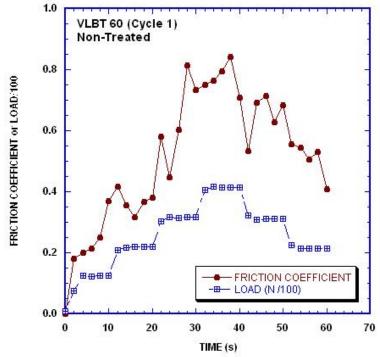


Figure 1. First cycle load and friction coefficient for the non-treated pair. Note that the load is divided by 100 to fit on the same vertical scale. The friction coefficient rises and falls similar to the load.

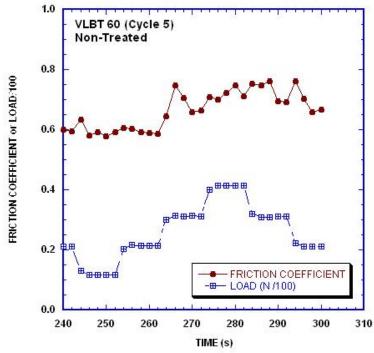


Figure 2. Fifth cycle load and friction coefficient for the non-treated pair. The friction is not as well correlated with the load after running-in.

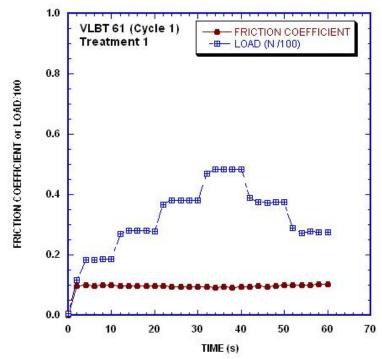
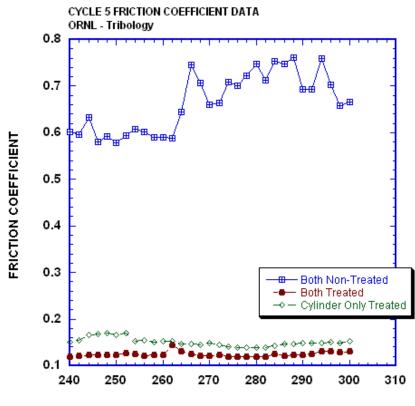


Figure 3. First cycle load and friction coefficient for self-mated Treatment 1. The friction coefficient does not follow the changes in load.

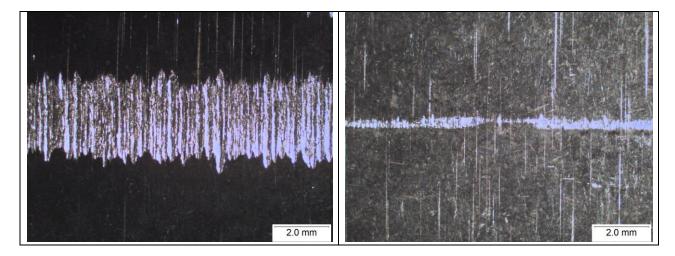


TIME (s)

Figure 4. Comparison of friction versus time behavior of three conditions under the last cycle of a variable load friction test.

4.2 Wear Images.

There was very little wear on the treated specimens compared with that of the non-treated specimen combinations (see Figures 5 and 6). The reduction in severe damage to both the flat specimens and the cylinder specimens is obvious. Scoring and adhesive wear dominate the non-treated specimen, while a smaller amount of abrasive wear occurs with the treated specimens.



Non-treated Treatment 1		
	Non-treated	Treatment 1

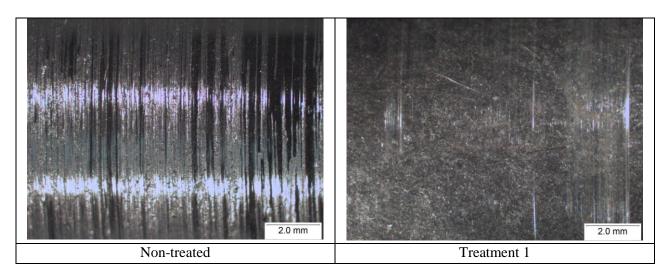


Figure 5. Comparison of flat specimens from two self-mated tests (VLBT 60, 61).

Figure 6. Cylinder specimens from two self-mated tests (VLBT 60, 61).

Of the treatments examined, the best wear results were when both surfaces were treated. When only one side was treated, there was definitely an advantage over non-treated, but there was also a greater chance of transition to scuffing or localized adhesion if a small spot happens to develop an open area or pick up a fragment of debris.

4.5 Thermal Imaging Results.

A high-speed infrared camera was positioned perpendicular to the axis of the cylinder and tilted down approximately 11° in order to view the cavity formed between the cylinder and the flat plate. The emissivity of the contact cavity between a cylinder and a flat plate has an emissivity approaching one due to the multiple reflections between their surfaces. This temperature was recorded during the variable load friction test for all three conditions; both surfaces non-treated, Cylinder only treated, and both surfaces treated. Figure 7 shows a plot of the contact temperature as a function of time. Overall temperature variations during the tests were one degree or less due to the large heat-sink volume compared to the thin heat generating contact area. However, the load cycle is clearly indicated by a one degree temperature rise when both surfaces were non-treated. This load cycle is much less evident during the cylinder only treated test. In this case the variability of the contact temperature is lower and it is not clear when the load is applied. Under the test condition where both the cylinder and the flat plate are both treated with RF85 (VLBT63), the contact temperature variability is greatly reduced and the overall temperature is lower than the cases where one or both of the surfaces are untreated.

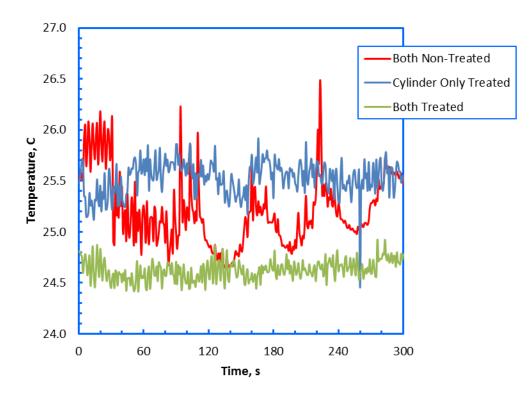


Figure 7. Comparison of Contact Temperature versus time behavior of three conditions under a variable load friction test.

5.0 Conclusions

Based on friction and wear tests of materials provided by BTN, the following conclusions were obtained.

- The BTN treatment, when applied to both sliding parts, reduced the kinetic friction coefficient of the steel couples by more than 75%.
- Treatment of both mating parts seemed to work better than treating only the cylinder specimen and not the flat specimen,
- Wear was significantly reduced by the surface treatment.
- Because only one test was conducted per condition, the repeatability of the results reported cannot be established and further testing under the conditions of the final application is recommended.
- The BTN treatment, when applied to both sliding parts, reduced the contact temperature and the contact temperature variability.

6.0 Raw Data Availability

The raw data is available in spreadsheet form for each test, as indicated by the example for test number VLBT-63 on the following page.

YCLE 1	eatmed cyl on non			0.1 m/s				
ïme (s)	Avg Norm F (N)	St dev Norm F (N)	Avg Fric F (N)	St dev Fric F (N)	Avg COF	St dev COF	Avg Spd (RPM)	St dev Spd (RPN
0	0.633501	0.737687	0.231813	0.176435	0	0	0.061109	0.04443
2.012			1.049257	0.651855	0.112396	0.069826		0.0118
4.013			1.606928	0.339863	0.108344	0.022915		0.0120
6.015			1.671237	0.344655	0.110862	0.022863		0.0118
8.016			1.693774	0.332244	0.112359	0.02204		0.0114
10.016			1.69281	0.375649	0.113908	0.025277		0.0117
12.015			2.54452	0.491745	0.10922	0.021107		0.0116
14.016			2.728598	0.42266	0.110976	0.01719		0.0117
16.014			2.720301	0.4395	0.1107	0.017885		0.0116
18.015			2.803846	0.420078	0.11411	0.017096		0.0117
20.013			2.806023	0.459284	0.114603	0.018758		0.011
22.014			3.646723	0.511467	0.109522	0.015361		0.0114
24.015			3.806016	0.456621	0.110373	0.013242		0.01
26.016			3.820291	0.457427	0.111083	0.013301		0.0115
28.015			3.843595	0.505543	0.111434	0.014657		0.0116
30.014			3.869058	0.524729	0.11275	0.015291		0.0117
32.016	43.0862	3.405612	4.728173	0.664431	0.109738	0.015421	0.097799	0.0115
34.015			4.782757	0.640829	0.107348	0.014383		0.0119
36.016	44.467063	0.844722	4.941836	0.635467	0.111135	0.014291	0.097954	0.0116
38.015	44.514244	0.87954	4.878115	0.601231	0.109585	0.013506	0.098448	0.0115
40.013	44.487267	0.974145	4.972902	0.601318	0.111783	0.013517	0.098372	0.0116
42.015	35.161129	3.156072	4.038861	0.541935	0.114867	0.015413	0.09862	0.0114
44.017	33.857408	0.840107	4.01115	0.468962	0.118472	0.013851	0.098471	0.0118
46.015	33.850721	0.85646	3.941558	0.470454	0.116439	0.013898	0.098227	0.0116
48.016	33.869719	0.942808	4.045446	0.430946	0.119441	0.012724	0.09777	0.0120
50.015	33.91845	0.85269	4.017698	0.457436	0.118452	0.013486	0.097721	0.0120
52.015	25.245884	2.841487	3.229032	0.60219	0.127903	0.023853	0.098484	0.0115
54.015	24.048633	0.927394	3.027841	0.446396	0.125905	0.018562	0.098367	0.0117
56.015	23.973585	0.905161	3.115544	0.399897	0.129957	0.016681	0.098524	0.011
58.016	23.997434	0.805113	3.106069	0.434793	0.129433	0.018118	0.098423	0.0117
60.015	24.046825	0.920399	3.131194	0.49966	0.130212	0.020779	0.098488	0.011
YCLE 5								
ime (s)	Avg Norm F (N)	St dev Norm F (N)	Avg Fric F (N)	St dev Fric F (N)	Avg COF	St dev COF	Avg Spd (RPM)	St dev Spd (RPI
240.018			3.581111	0.51504	0.150006	0.021574	0.009534	0.0115
240.010	23 873083	0 879737						
242 016								
242.016	23.902958	0.881616	3.677432	0.505706	0.153848	0.021157	0.098198	0.0114
244.008	23.902958 15.44335	0.881616 2.862897	3.677432 2.551765	0.505706 0.440409	0.153848 0.165234	0.021157 0.028518	0.098198 0.097772	0.0114 0.0118
244.008 246.015	23.902958 15.44335 14.227213	0.881616 2.862897 0.863331	3.677432 2.551765 2.394595	0.505706 0.440409 0.415082	0.153848 0.165234 0.168311	0.021157 0.028518 0.029175	0.098198 0.097772 0.097966	0.0114 0.0118 0.0118
244.008 246.015 248.015	23.902958 15.44335 14.227213 14.308775	0.881616 2.862897 0.863331 0.833797	3.677432 2.551765 2.394595 2.43321	0.505706 0.440409 0.415082 0.472	0.153848 0.165234 0.168311 0.17005	0.021157 0.028518 0.029175 0.032987	0.098198 0.097772 0.097966 0.098153	0.0114 0.0118 0.0118 0.0113
244.008 246.015 248.015 250.016	23.902958 15.44335 14.227213 14.308775 14.203938	0.881616 2.862897 0.863331 0.833797 0.928695	3.677432 2.551765 2.394595 2.43321 2.361013	0.505706 0.440409 0.415082 0.472 0.380747	0.153848 0.165234 0.168311 0.17005 0.166222	0.021157 0.028518 0.029175 0.032987 0.026806	0.098198 0.097772 0.097966 0.098153 0.098627	0.0114 0.0118 0.0118 0.0113 0.0114
244.008 246.015 248.015 250.016 252.017	23.902958 15.44335 14.227213 14.308775 14.203938 14.218977	0.881616 2.862897 0.863331 0.833797 0.928695 0.837393	3.677432 2.551765 2.394595 2.43321 2.361013 2.421379	0.505706 0.440409 0.415082 0.472 0.380747 0.372449	0.153848 0.165234 0.168311 0.17005 0.166222 0.170292	0.021157 0.028518 0.029175 0.032987 0.026806 0.026194	0.098198 0.097772 0.097966 0.098153 0.098627 0.098499	0.0114 0.0118 0.0118 0.0113 0.0114 0.0114
244.008 246.015 248.015 250.016 252.017 254.015	23.902958 15.44335 14.227213 14.308775 14.203938 14.218977 23.163937	0.881616 2.862897 0.863331 0.833797 0.928695 0.837393 2.9774	3.677432 2.551765 2.394595 2.43321 2.361013 2.421379 3.516141	0.505706 0.440409 0.415082 0.472 0.380747 0.372449 0.659776	0.153848 0.165234 0.168311 0.17005 0.166222 0.170292 0.151794	0.021157 0.028518 0.029175 0.032987 0.026806 0.026194 0.028483	0.098198 0.097772 0.097966 0.098153 0.098627 0.098499 0.098354	0.0114 0.0118 0.0113 0.0114 0.0114 0.0114 0.0114
244.008 246.015 248.015 250.016 252.017 254.015 256.015	23.902958 15.44335 14.227213 14.308775 14.203938 14.218977 23.163937 24.430698	0.881616 2.862897 0.863331 0.833797 0.928695 0.837393 2.9774 0.89168	3.677432 2.551765 2.394595 2.43321 2.361013 2.421379 3.516141 3.773236	0.505706 0.440409 0.415082 0.472 0.380747 0.372449 0.659776 0.47573	0.153848 0.165234 0.168311 0.17005 0.166222 0.170292 0.151794 0.154447	0.021157 0.028518 0.029175 0.032987 0.026806 0.026194 0.028483 0.019473	0.098198 0.097772 0.097966 0.098153 0.098627 0.098499 0.098354 0.098354	0.0114 0.0118 0.0113 0.0114 0.0114 0.0114 0.0114
244.008 246.015 248.015 250.016 252.017 254.015 256.015 258.016	23.902958 15.44335 14.227213 14.308775 14.203938 14.218977 23.163937 24.430698 24.374219	0.881616 2.862897 0.863331 0.833797 0.928695 0.837393 2.9774 0.89168 0.850139	3.677432 2.551765 2.394595 2.43321 2.361013 2.421379 3.516141 3.773236 3.689388	0.505706 0.440409 0.415082 0.472 0.380747 0.372449 0.659776 0.47573 0.420003	0.153848 0.165234 0.168311 0.17005 0.166222 0.170292 0.151794 0.151364	0.021157 0.028518 0.029175 0.032987 0.026806 0.026194 0.028483 0.019473 0.017231	0.098198 0.097772 0.097966 0.098153 0.098627 0.098499 0.098354 0.098354	0.0114 0.0118 0.0118 0.0111 0.0114 0.0114 0.0114 0.0114 0.0114
244.008 246.015 248.015 250.016 252.017 254.015 256.015 258.016 260.016	23.902958 15.44335 14.227213 14.308775 14.203938 14.218977 23.163937 24.430698 24.374219 24.363084	0.881616 2.862897 0.863331 0.833797 0.928695 0.837393 2.9774 0.89168 0.850139 0.881776	3.677432 2.551765 2.394595 2.43321 2.361013 2.421379 3.516141 3.773236 3.689388 3.73903	0.505706 0.440409 0.415082 0.472 0.380747 0.372449 0.659776 0.47573 0.420003 0.464255	0.153848 0.165234 0.168311 0.17005 0.166222 0.170292 0.151794 0.154447 0.151364 0.153471	0.021157 0.028518 0.029175 0.032987 0.026806 0.026194 0.028483 0.019473 0.017231 0.019056	0.098198 0.097772 0.097966 0.098153 0.098627 0.098499 0.098354 0.098354 0.098858 0.097888	0.0114 0.0118 0.0118 0.0111 0.0114 0.0114 0.0114 0.0114 0.0113 0.0116
244.008 246.015 248.015 250.016 252.017 254.015 256.015 258.016 260.016 262.016	23.902958 15.44335 14.227213 14.308775 14.203938 14.218977 23.163937 24.430698 24.374219 24.363084 24.332922	0.881616 2.862897 0.863331 0.928695 0.837393 2.9774 0.89168 0.850139 0.881776 0.903976	3.677432 2.551765 2.394595 2.43321 2.361013 2.421379 3.516141 3.773236 3.689388 3.73903 3.710194	0.505706 0.440409 0.415082 0.472 0.380747 0.372449 0.659776 0.47573 0.42003 0.42003 0.464255 0.517928	0.153848 0.165234 0.168311 0.17005 0.166222 0.170292 0.151794 0.154447 0.151364 0.153471 0.152476	0.021157 0.028518 0.029175 0.032987 0.026806 0.026194 0.028483 0.019473 0.019473 0.017231 0.019056 0.021285	0.098198 0.097772 0.097966 0.098153 0.098627 0.098499 0.098354 0.098471 0.097888 0.097788	0.0114 0.0118 0.0118 0.0114 0.0114 0.0114 0.0114 0.0114 0.01115 0.0116
244.008 246.015 248.015 250.016 252.017 254.015 256.015 258.016 260.016 262.016 264.016	23.902958 15.44335 14.227213 14.308775 14.203938 14.218977 23.163937 24.430698 24.374219 24.363084 24.332922 32.850142	0.881616 2.862897 0.863331 0.928695 0.83797 0.928695 0.837393 2.9774 0.89168 0.850139 0.881776 0.903976 3.002666	3.677432 2.551765 2.394595 2.43321 2.361013 3.516141 3.773236 3.689388 3.73903 3.710194 4.849065	0.505706 0.440409 0.415082 0.472 0.380747 0.372449 0.659776 0.47573 0.42003 0.42003 0.464255 0.517928 0.68999	0.153848 0.165234 0.168311 0.17005 0.166222 0.170292 0.151794 0.151364 0.153471 0.152476 0.147612	0.021157 0.028518 0.029175 0.032987 0.026806 0.026194 0.028483 0.019473 0.019473 0.019756 0.021285 0.021004	0.098198 0.097772 0.097966 0.098153 0.098627 0.098499 0.098354 0.097888 0.097788 0.097788	0.0114 0.0118 0.0118 0.0112 0.0114 0.0114 0.0114 0.0114 0.0115 0.0116 0.0116
244.008 246.015 248.015 250.016 252.017 254.015 256.015 258.016 260.016 262.016 264.016 266.015	23.902958 15.44335 14.227213 14.308775 14.203938 14.218977 23.163937 24.430698 24.374219 24.363084 24.332922 32.850142 34.075058	0.881616 2.862897 0.863331 0.833797 0.928695 0.837393 2.9774 0.89168 0.850139 0.881776 0.903976 3.002666 0.885818	3.677432 2.551765 2.394595 2.43321 2.361013 3.516141 3.773236 3.689388 3.73903 3.710194 4.849065 4.992459	0.505706 0.440409 0.415082 0.415082 0.380747 0.372449 0.659776 0.47573 0.42003 0.44255 0.517928 0.68999 0.593538	0.153848 0.165234 0.168311 0.17005 0.166222 0.170292 0.151794 0.151364 0.153471 0.152476 0.147612 0.146514	0.021157 0.028518 0.029175 0.032987 0.026806 0.026194 0.028483 0.019473 0.017231 0.019756 0.021285 0.021004 0.017419	0.098198 0.097772 0.097966 0.098153 0.098453 0.098471 0.098471 0.097888 0.097788 0.097788 0.097788	0.0114 0.0113 0.0113 0.0114 0.0114 0.0114 0.0114 0.0111 0.0111 0.01116 0.01114
244.008 246.015 248.015 250.016 252.017 254.015 256.015 260.016 262.016 264.016 266.015 268.015	23.902958 15.44335 14.227213 14.308775 14.203938 14.218977 23.163937 24.430698 24.374219 24.363084 24.332922 32.850142 34.075058 34.127175	0.881616 2.862897 0.863331 0.833797 0.928695 0.837393 2.9774 0.89168 0.850139 0.881776 0.903976 3.002666 0.885818 0.898788	3.677432 2.551765 2.394595 2.43321 2.361013 2.421379 3.516141 3.773236 3.689388 3.73903 3.710194 4.849065 4.992459 4.952828	0.505706 0.440409 0.415082 0.472 0.380747 0.372449 0.659776 0.47573 0.42003 0.446255 0.517928 0.68999 0.593538	0.153848 0.165234 0.168311 0.17005 0.166222 0.170292 0.151794 0.151364 0.153471 0.152476 0.147612 0.146514 0.145129	0.021157 0.028518 0.029175 0.032987 0.026806 0.026194 0.028483 0.019473 0.019473 0.019056 0.021285 0.021004 0.017419 0.019272	0.098198 0.097772 0.097966 0.098153 0.098627 0.098454 0.098454 0.097888 0.097788 0.097788 0.097788 0.097787 0.098341 0.098547	0.0114 0.0113 0.0113 0.0114 0.0114 0.0114 0.0114 0.0113 0.0114 0.01115 0.0114 0.01115 0.0114
244.008 246.015 248.015 250.016 252.017 254.015 256.015 260.016 262.016 264.016 266.015 268.015 268.015	23.902958 15.44335 14.227213 14.308775 14.203938 14.218977 23.163937 24.430698 24.374219 24.363084 24.332922 32.850142 34.075058 34.127175 33.865845	0.881616 2.862897 0.863331 0.833797 0.928695 0.837393 2.9774 0.89168 0.850139 0.850139 0.881776 0.903976 3.002666 0.885818 0.898788 0.955232	3.677432 2.551765 2.394595 2.43321 2.361013 2.421379 3.516141 3.773236 3.689388 3.73903 3.710194 4.849065 4.992459 4.952828 5.01753	0.505706 0.440409 0.415082 0.472 0.380747 0.372449 0.659776 0.47573 0.420003 0.464255 0.517928 0.68999 0.593538 0.657714 0.668097	0.153848 0.165234 0.168311 0.17005 0.166222 0.170292 0.151794 0.151364 0.153471 0.152476 0.147612 0.146514 0.145129 0.148159	0.021157 0.028518 0.029175 0.032987 0.026806 0.026194 0.028483 0.019473 0.019473 0.019056 0.021285 0.021004 0.017419 0.019272 0.019728	0.098198 0.097772 0.097966 0.098153 0.098627 0.098454 0.098454 0.09788 0.097788 0.097788 0.097787 0.098341 0.098547 0.098503 0.098503	0.0114 0.0113 0.0113 0.0114 0.0114 0.0114 0.0114 0.0111 0.0111 0.0111 0.0111 0.0111 0.0111
244.008 246.015 248.015 250.016 252.017 254.015 256.015 260.016 262.016 264.016 266.015 268.015 270.017 272.018	23.902958 15.44335 14.227213 14.308775 14.203938 14.218977 23.163937 24.430698 24.374219 24.363084 24.363084 24.332922 32.850142 34.075058 34.127175 33.865845 34.041538	0.881616 2.862897 0.863331 0.833797 0.928695 0.837393 2.9774 0.89168 0.850139 0.850139 0.881776 0.903976 3.002666 0.885818 0.898788 0.955232 0.918802	3.677432 2.551765 2.394595 2.43321 2.361013 2.421379 3.516141 3.773236 3.689388 3.73903 3.710194 4.849065 4.992459 4.952828 5.01753 4.916604	0.505706 0.440409 0.415082 0.472 0.380747 0.372449 0.659776 0.47573 0.42003 0.464255 0.517928 0.68999 0.593538 0.657714 0.668097 0.609315	0.153848 0.165234 0.168311 0.17005 0.166222 0.170292 0.151794 0.1514747 0.151364 0.153471 0.152476 0.147612 0.146514 0.145129 0.148159 0.14443	0.021157 0.028518 0.029175 0.032987 0.026806 0.026194 0.028483 0.019473 0.019473 0.017231 0.019056 0.021285 0.021004 0.017419 0.019272 0.019728 0.019728	0.098198 0.097772 0.097966 0.098153 0.098627 0.098354 0.098344 0.098471 0.09788 0.097788 0.097788 0.097787 0.098341 0.098547 0.098543 0.098597	0.0114 0.0113 0.0113 0.0114 0.0114 0.0114 0.0114 0.0111 0.0111 0.0111 0.0111 0.0111 0.0111 0.0111 0.0111
244.008 246.015 248.015 250.016 252.017 254.015 256.015 258.016 262.016 264.016 264.016 264.015 268.015 270.017 272.018 274.018	23.902958 15.44335 14.227213 14.308775 14.203938 14.218977 23.163937 24.430698 24.374219 24.363084 24.374219 24.363084 34.075058 34.075058 34.127175 33.865845 34.041538	0.881616 2.862897 0.863331 0.833797 0.928695 0.837393 2.9774 0.89168 0.850139 0.881776 0.903976 3.002666 0.885818 0.898788 0.955232 0.918802 3.156485	3.677432 2.551765 2.394595 2.43321 2.361013 2.421379 3.516141 3.773236 3.689388 3.73903 3.710194 4.849065 4.992459 4.952828 5.01753 4.916604 6.072784	0.505706 0.440409 0.415082 0.472 0.380747 0.372449 0.659776 0.47573 0.42003 0.464255 0.547928 0.68999 0.593538 0.657714 0.668097 0.669315 0.748989	0.153848 0.165234 0.168311 0.17005 0.166222 0.170292 0.151794 0.1514447 0.151364 0.153471 0.152476 0.147612 0.146514 0.145129 0.148159 0.14413 0.141063	0.021157 0.028518 0.029175 0.032987 0.026806 0.026194 0.028483 0.019473 0.017731 0.019056 0.021285 0.021004 0.017419 0.019272 0.019728 0.017899 0.017398	0.098198 0.097772 0.097966 0.098153 0.098627 0.098354 0.098354 0.098471 0.09788 0.097788 0.097788 0.097917 0.098341 0.098547 0.098503 0.098503 0.098597	0.011 0.011 0.011 0.011 0.011 0.011 0.011 0.011 0.011 0.011 0.011 0.011 0.011 0.011
244.008 246.015 248.015 250.016 252.017 254.015 258.016 260.016 264.016 264.016 266.015 268.015 270.017 272.018 274.018	23.902958 15.44335 14.227213 14.308775 14.203938 14.218977 23.163937 24.430698 24.374219 24.363084 24.374219 24.363084 24.332922 32.850142 34.075058 34.127175 33.865845 34.041538 43.050298 44.161853	0.881616 2.862897 0.863331 0.833797 0.928695 0.837393 2.9774 0.89168 0.850139 0.881776 0.903976 3.002666 0.885818 0.898788 0.955232 0.918802 3.156485 0.91436	3.677432 2.551765 2.394595 2.43321 2.361013 2.421379 3.516141 3.773236 3.689388 3.73903 3.710194 4.849065 4.992459 4.952828 5.01753 4.916604 6.072784 6.103743	0.505706 0.440409 0.415082 0.472 0.380747 0.372449 0.659776 0.47573 0.420003 0.464255 0.517928 0.68999 0.593538 0.657714 0.668097 0.609315 0.748989 0.805926	0.153848 0.165234 0.168311 0.17005 0.166222 0.170292 0.151794 0.151364 0.15136471 0.152476 0.147612 0.146514 0.145129 0.148159 0.14413 0.141063 0.138213	0.021157 0.028518 0.029175 0.032987 0.026806 0.026194 0.028483 0.019473 0.017231 0.019056 0.021285 0.021004 0.017419 0.019272 0.019728 0.019728 0.017398 0.017398	0.098198 0.097772 0.097966 0.098153 0.098627 0.098499 0.098354 0.098471 0.09788 0.097788 0.097788 0.097917 0.098341 0.098503 0.098503 0.098597 0.098234 0.098721	0.0114 0.0113 0.0113 0.0114 0.0114 0.0114 0.0114 0.0111 0.0111 0.0111 0.0111 0.0111 0.0111 0.0111 0.0111 0.0111
244.008 246.015 248.015 250.016 252.017 254.015 256.015 266.016 266.016 266.015 268.015 268.015 270.017 272.018 274.018 274.018	23.902958 15.44335 14.227213 14.308775 14.203938 14.218977 23.163937 24.430698 24.374219 24.363084 24.332922 32.850142 34.075058 34.127175 33.865845 34.041538 43.050298 44.161853	0.881616 2.862897 0.863331 0.833797 0.928695 0.837393 2.9774 0.89168 0.850139 0.881776 0.903976 3.002666 0.885818 0.938788 0.955232 0.918802 3.156485 0.91436 0.908662	3.677432 2.551765 2.394595 2.43321 2.361013 2.421379 3.516141 3.773236 3.689388 3.73903 3.710194 4.849065 4.992459 4.952828 5.01753 4.916604 6.072784 6.103743 6.163128	0.505706 0.440409 0.415082 0.472 0.380747 0.372449 0.659776 0.47573 0.420003 0.464255 0.517928 0.68999 0.593538 0.657714 0.668997 0.609315 0.748989 0.805926 0.7827	0.153848 0.165234 0.168311 0.17005 0.166222 0.170292 0.151794 0.151364 0.15136471 0.152476 0.147612 0.146514 0.1445129 0.1448159 0.14443 0.141063 0.138213 0.138663	0.021157 0.028518 0.029175 0.032987 0.026806 0.026194 0.028483 0.019473 0.017231 0.019056 0.021285 0.021004 0.017419 0.019722 0.019728 0.017899 0.017398 0.017398 0.018249 0.016935	0.098198 0.097772 0.097966 0.098153 0.098627 0.098499 0.098354 0.098471 0.09788 0.097788 0.097788 0.097787 0.098341 0.098503 0.098597 0.098234 0.097721 0.097635 0.098092	0.0114 0.0113 0.0113 0.0114 0.0114 0.0114 0.0114 0.0111 0.0111 0.0111 0.0111 0.0111 0.0111 0.0111 0.0111 0.0111
244.008 246.015 248.015 250.016 252.017 254.015 256.015 258.016 260.016 262.016 264.016 268.015 268.015 270.017 272.018 274.018 274.018 274.018	23.902958 15.44335 14.227213 14.308775 14.203938 14.218977 23.163937 24.430698 24.374219 24.363084 24.332922 32.850142 34.075058 34.127175 33.865845 34.041538 43.050298 44.161853 44.446917 44.406681	0.881616 2.862897 0.863331 0.833797 0.928695 0.837393 2.9774 0.89168 0.850139 0.851189 0.881776 0.903976 3.002666 0.885818 0.898788 0.9955232 0.915802 3.156485 0.91436 0.908662 0.826196	3.677432 2.551765 2.394595 2.43321 2.361013 3.516141 3.773236 3.689388 3.77303 3.710194 4.849065 4.992459 4.952828 5.01753 4.916604 6.072784 6.103743 6.163128	0.505706 0.440409 0.415082 0.472 0.380747 0.372449 0.659776 0.47573 0.420003 0.464255 0.517928 0.68999 0.593538 0.657714 0.668097 0.668097 0.669315 0.748389 0.805926 0.7527 0.743406	0.153848 0.165234 0.168311 0.17005 0.166222 0.170292 0.151794 0.151364 0.153471 0.152476 0.147612 0.146514 0.145129 0.1441063 0.1441063 0.138213 0.138663 0.139141	0.021157 0.028518 0.029175 0.032987 0.026806 0.026194 0.028483 0.019473 0.019473 0.019056 0.021285 0.021004 0.017419 0.019272 0.019728 0.017398 0.017398 0.017398 0.018249 0.016935	0.098198 0.097772 0.097966 0.0986153 0.098627 0.098451 0.098451 0.098451 0.097888 0.097788 0.097788 0.097917 0.098503 0.098503 0.098503 0.098234 0.097721 0.097535 0.098092	0.0114 0.0113 0.0113 0.0114 0.0114 0.0114 0.0114 0.0111 0.0111 0.0111 0.0111 0.0111 0.0111 0.0111 0.0111 0.0111 0.0111
244.008 246.015 248.015 250.016 252.017 254.015 256.015 258.016 262.016 262.016 264.016 266.015 268.015 270.017 272.018 274.018 276.018 276.018	23.902958 15.44335 14.227213 14.308775 14.203938 14.218977 23.163937 24.430698 24.374219 24.363084 24.332922 32.850142 34.075058 34.127175 33.865845 34.0471538 43.050298 44.161853 44.446917 44.406681	0.881616 2.862897 0.863331 0.833797 0.928695 0.837393 2.9774 0.89168 0.850139 0.881776 0.903976 3.002666 0.885818 0.903976 3.002666 0.885818 0.995732 0.918802 3.156485 0.918802 0.918802 0.91845 0.91845	3.677432 2.551765 2.394595 2.43321 2.361013 3.71379 3.516141 3.773236 3.689388 3.773903 3.710194 4.849065 4.992459 4.952828 5.01753 4.916604 6.072784 6.103743 6.163128 6.173763	0.505706 0.440409 0.415082 0.472 0.380747 0.372449 0.659776 0.47573 0.420003 0.464255 0.517928 0.68999 0.593538 0.657714 0.668097 0.609315 0.748989 0.805926 0.7527 0.743406	0.153848 0.165234 0.168311 0.17005 0.166222 0.170292 0.151794 0.151364 0.153471 0.152476 0.147612 0.146514 0.145129 0.1445129 0.14413 0.14403 0.1441063 0.138213 0.138663 0.139141 0.139065	0.021157 0.028518 0.029175 0.032987 0.026806 0.026194 0.028483 0.019473 0.019056 0.021285 0.021004 0.017419 0.019728 0.019728 0.019728 0.019739 0.017398 0.017398 0.016935 0.016741 0.015292	0.098198 0.097772 0.097966 0.0986153 0.098627 0.098451 0.098451 0.097888 0.097788 0.097788 0.097917 0.098547 0.098503 0.098503 0.098503 0.098234 0.097721 0.097635 0.098092 0.098321 0.098321	0.0114 0.0113 0.0113 0.0114 0.0114 0.0114 0.0114 0.0114 0.0114 0.0111 0.0111 0.0111 0.0111 0.0111 0.0111 0.0111 0.0111 0.0111 0.0111 0.0111 0.0111 0.0111 0.0111
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