SHADING EFFECTS OF DECIDUOUS TREES¹

by Robert J. Youngberg

The shading impact of trees on the energy consumption of buildings, and in particular solar systems is not easy to estimate. With support from the Lincoln Electric system and the U.S. Department of Energy a project was started to monitor deciduous trees, both summer and winter for two years. The project was designed to provide data on widely used tree species in the Midwest. At the present time, information on the effectiveness of deciduous trees to provide shade in the summer but also allow sunlight penetration in the winter is minimal.

This project measured solar radiation penetration through the canopy of six trees twice a year for two years. Sites were selected which contained 'modern' healthy tree species which were currently popular and available from nurseries. They were also selected for uniformity in size, age and accessability for monitoring. Both the Lincoln and state forestries were very helpful in the selection and location of these trees.

It is essential when monitoring sunlight penetration through the tree canopy that the measurement reflect the average condition. Wide variations in measurements were experienced due to bare branches, wind, sun flecks and reflection from the surroundings. A mobile, track mounted thermopile type pyranometer was used to measure a grid 9 readings wide and 7 readings long each hour under the tree canopy. Another pyranometer was located in the full sun outside the tree canopy and a battery powered data logger intercepted three readings over 30 seconds for each sensor. A battery powered 'tank' programmed to stop every 4.3 ft. for 30 seconds provided the locomotion. In this fashion, 63 readings in a grid pattern were obtained each hour for 6 to 8 hours per day. The track was moved after each 'run' (9 readings) through the shade or 7 times each hour. The readings were recorded on an audio tape recorder connected to the data logger. Each day's data was then played through an analog to digital converter and stored on computer tape for further analysis.

The data were analyzed from three viewpoints both summer and winter. First was how many watts per square meter was being blocked by the tree. This varied continuously from tree to tree, time of year, time of day and location within the tree itself. Although this information is in itself of great value to plant scientists it was not of central concern to the project. The following charts show the amount of solar radiation blocked by a sycamore tree in the full leaf condition (Fig. 1). These figures show a blockage of about 700 watts per square meter during the summer. A similar hour for the winter shows a 350-450 w/m² blockage. Of interest is the general uniformity (except for sun flecks) of blockage both top to bottom and side to side within the tree canopy,

What we are more interested in for design purposes, however, is the amount of solar radiation penetrating the canopy. Figure 2 and 3 show these figures are in the range of $500-600 \text{ w/m}^2$ during the bare branch condition and typically less than 100 during the full leaf condition. Of even more interest for designers in applying this information to other locations with trees of this type is a percentage figure.





^{1.} Presented at the Trees for Nebraska Conference in 1982.

REC NO.	SOLAR TIME	SR#1 NT/N	SR#2 NT/M	RUN DIS FT.	T X FT.	Υ Fĭ.	21 NT/M	12 2
127 128 129 130 131 132 133 134 135	1008 1008 1007 1007 1010 1010 1011 1011	770 778 794 209 129 211 187 140 550	727 727 730 731 732 731 732 732 732 732	-5555555555	-8.73 -5.67 -2.66 .42 3.47 6.57 9.67 12.78 15.94	-15.64 -12.62 -9.59 -6.58 -3.60 61 2.32 5.29 8.18	-43 -51 -64 522 603 521 545 592 183	-5.92 -7.00 -8.83 71.37 82.37 71.22 74.51 80.84 25.01
136 137 138 139 140 141 142 143 144	1014 1015 1015 1016 1016 1017 1017 1018 1018	772 767 291 95 185 378 380 461 766	738 738 738 740 741 742 741 741 741 742	0 0 0 0 0 0 0 0	-12.64 -9.53 -6.35 -3.19 0.00 3.21 6.42 9.68 12.90	-11.67 -8.70 -5.30 -2.88 0.00 2.86 5.73 8.53 11.38	-34 -30 457 645 556 364 361 281 -24	-4.61 -4.01 61.93 87.15 75.05 49.04 48.74 37.86 -3.19
145 146 147 148 149 150 151 152 153	1023 1023 1024 1024 1025 1025 1025 1026 1026 1027	783 781 312 63 57 65 66 74 385	745 746 747 750 751 751 753 754	8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	-18.34 -15.03 -11.72 -8.40 -5.04 -1.70 1.71 5.06 8.52	-4.84 -2.09 3.45 6.21 8.92 11.62 14.31 16.95	-38 -35 435 696 696 694 686 625 679 369	-5.14 -4.68 58.26 91.61 52.47 91.41 91.20 90.20 48.93
154 155 156 157 158 159 160 161 162	1030 1031 1031 1032 1032 1033 1033 1034	778 320 67 61 354 207 320 211	755 757 758 760 760 761 762 763 763	13 13 13 13 13 13 13 13 13	-21.56 -18.14 -14.69 -11.25 -7.75 -4.30 75 2.71 6.31	09 2.52 5.22 7.80 10.43 13.00 15.57 18.11 20.62	-23 438 591 599 701 408 555 443 552	-3.09 57.77 91.15 91.96 53.55 72.83 58.03 72.31
163 164 165 166 167 168 169 170 171	1037 1037 1038 1038 1039 1039 1040 1040 1040	774 774 312 74 82 61 109 80 323	758 758 759 760 762 764 765 765 765	18 18 18 18 19 18 18 18	-24.40 -20.87 -17.28 -13.73 -10.09 -6.53 -2.94 .73 4.47	4.96 7.41 9.98 12.41 14.91 17.32 19.75 22.13 24.49	-17 -16 447 687 681 702 655 685 442	-2.18 -2.08 58.91 90.33 89.27 92.00 65.75 89.55 57.76
172 173 174 175 176 177 178 179 190	1043 1044 1045 1045 1045 1045 1045 1047 1047	780 777 326 79 76 64 112 312 784	763 765 766 766 769 771 772 773	24 24 24 24 24 24 24 24 24 24	-27.42 -23.72 -20.09 -16.32 -12.67 -3.87 -5.20 -1.36 2.32	10.94 13.42 15.71 18.11 20.38 22.71 24.96 27.21 29.44	-17 -14 439 687 690 705 659 460 +12	-2.18 -1.80 57.38 95.71 90.04 91.74 85.47 59.64 -1.49
151 182 183 184 185 186 185 186 187 188 188	1050 1051 1051 1052 1052 1053 1053 1054	769 792 444 86 75 74 243 664 812	775 776 777 778 779 780 782 782 784 785	30 20 30 30 30 30 30 30 30 30	-29.89 -26.16 -22.29 -16.55 -14.64 -10.38 -6.92 -3.16 .85	17.39 19.54 21.84 23.96 25.19 28.29 30.43 32.50 34.57	-13 -16 333 693 704 705 540 120 -27	-1.70 -2.02 42.84 88.98 90.42 90.56 58.99 15.27 -3.47

This is a typical one hour recording of data from 10:08 to 10:54 in September. SR#1 is the sensor reading in the shade of the canopy and SR#2 is the full-sun reading in immediate area. The run distance is the track position from the tree trunk. 'X' and 'Y' are calculated coordinates for plotting purposes and Z1 is the unit difference between the two readings in watts per square meter and Z2 is the percentage difference. Negative differences are due to local reflections and will be minimized after calibration constants are applied to the data.









Figure 4 shows this tree to block 40-50% of the solar radiation in the bare branch winter condition and in the full leaf condition block an almost uniform 90%. It is interesting to note that this is very close to the expected diffuse component (vs. direct) of total solar radiation. Figure 5 shows this information for the full leaf condition.









Preliminary analysis of the other monitored trees show a typical 90% blockage during the summer months and a winter blockage ranging from 25 to 60%. A statistical analysis including curve fitting will be performed on the data to derive a model by which this information can be applied to other locations.