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White Paper

Know Your Environment

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Know Your Environment

Temperature variation in uncontrolled environments is driven by diurnal cycling (rise and fall of the sun). As such, the statistics of temperatures in uncontrolled environments can be determined through an assessment of climatic data and an understanding of temperature rise within an enclosed structure.

There were two sources of climatic data used in this assessment: National Climatic Data Center (NCDC) and CONFIDENTIAL North American Ambient Weather Study (1988).

The NCDC provided two databases from which to provide some understanding of the probability of any one temperature occurring over long periods of time in the United States.

- CLIMXX: Climatography of the U.S., No. XX: This publication presents normals of average monthly and annual maximum, minimum, and mean temperature (degrees F), for 275 individual cities for the 1961-90 period.
- HCS 4-1 Historical Climatography Series 4-1: Area-Weighted State, Regional, and National Monthly Temperature 1971 – 2000 (and previous normals periods)

Probabilities were determined by taking the raw data provided by NCDC and fitting them to distributions. For the CLIM data, temperatures were found to best fit Weibull distribution when separated into “cold”, “warm”, and “hot” categories. The rationale for this can be seen in Figure 1, where the statistical variation in the daily maximum temperature seems to divide itself into three groupings. For the HCS data, temperatures were found to best fit Normal distributions. The results are displayed in Figure 2 and Figure 3. It can be seen that for the average maximum temperature, both data sets relatively close in agreement, with values of approximately 12 to 16ºC. It is important to note that this is only for maximum temperatures. Assuming a simple binary model for daily temperature distribution, half the day is subjected to maximum temperature and half the day is subjected to minimum temperature. This minimum temperature is most likely approximately 7 to 9ºC colder than the maximum temperature.

For extreme temperatures, these two distributions begin to diverge. The HCS data claims that the probability of maximum temperatures exceeding 25ºC (77ºF) on any given day in any given USA city is less than 1%, while the CLIM data suggest this does not occur until the outdoor temperatures reach 37ºC (99ºF).

An alternative approach is to use environmental data obtained by CONFIDENTIAL, which breaks down temperature exposure by cumulative hours over a ten-year period (see Table 1). Comparing the CONFIDENTIAL dataset to the NCDC dataset we find good correlation. The CLIM data seems to be in close agreement with the CONFIDENTIAL data weighed by population. This is especially true when one takes the CLIM data and divides the 1-CDF function by 4 to take into account that maximum temperatures only occur for 6 hours per day, assuming equivalent periods for max temp, min temp, ramp up, and ramp down.

Once the ambient conditions are known, the next step is to understand temperature rise within the enclosure due to direct exposure to the sun. Data on the statistical variation of temperature rise is currently unknown. However, review of information from DfR Solutions, CONFIDENTIAL, and a major PC manufacturer strongly suggests that maximum temperature rise is driven by the size of the container (see Table 3 and Figure 4). Given that the size of an outdoor cabinet would be roughly with the order of magnitude of a car trunk, it can be assumed that the temperature rise would be roughly similar (20-25C).

The influence of ambient temperature on temperature rise can be seen in Figure 5. At temperatures of 35C, the maximum temperature rise reaches 30C. As the ambient temperature drops to 30C, the maximum temperature rise falls to 20C. At a lower ambient temperature of 25C, the maximum temperature rise falls even further to 10C. These observations combined with statistical information on ambient temperature leads to the answers provided in the following figures.

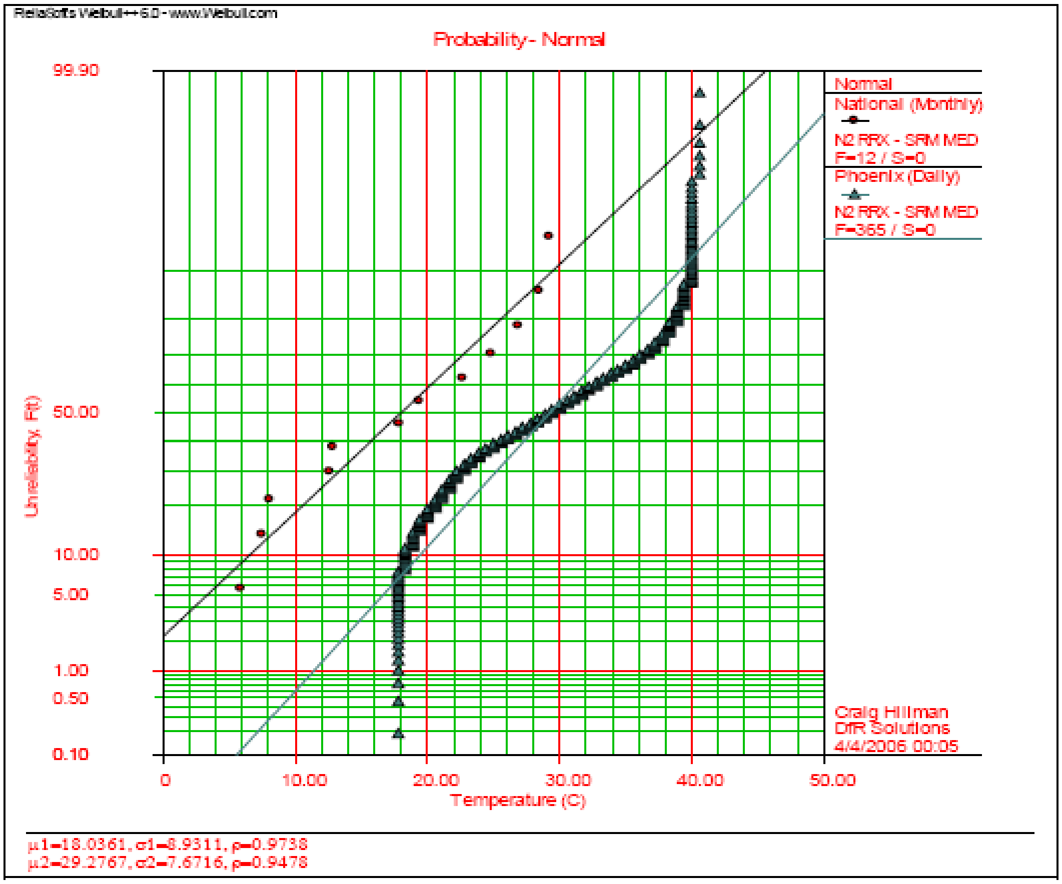

Figure 1: Distributions for daily maximum temperatures in Phoenix, AZ (green triangles) and monthly maximum temperatures from an average of 275 American cities (red circles)

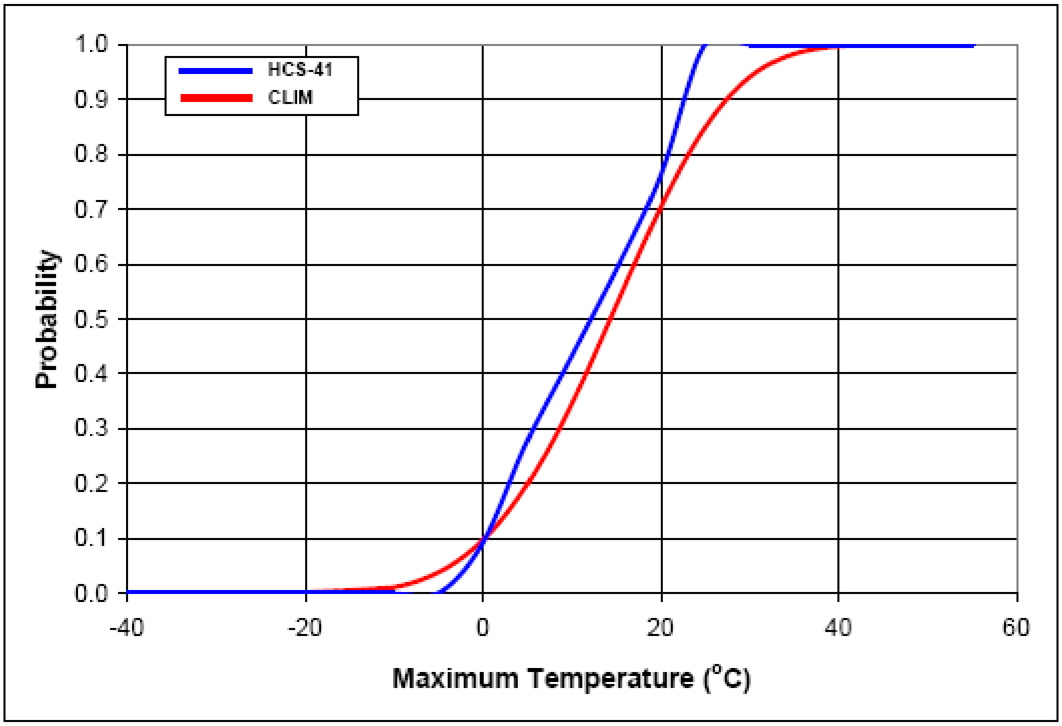

Figure 2: Probability distribution of maximum temperature based upon data from CLIMXX and HCS-41

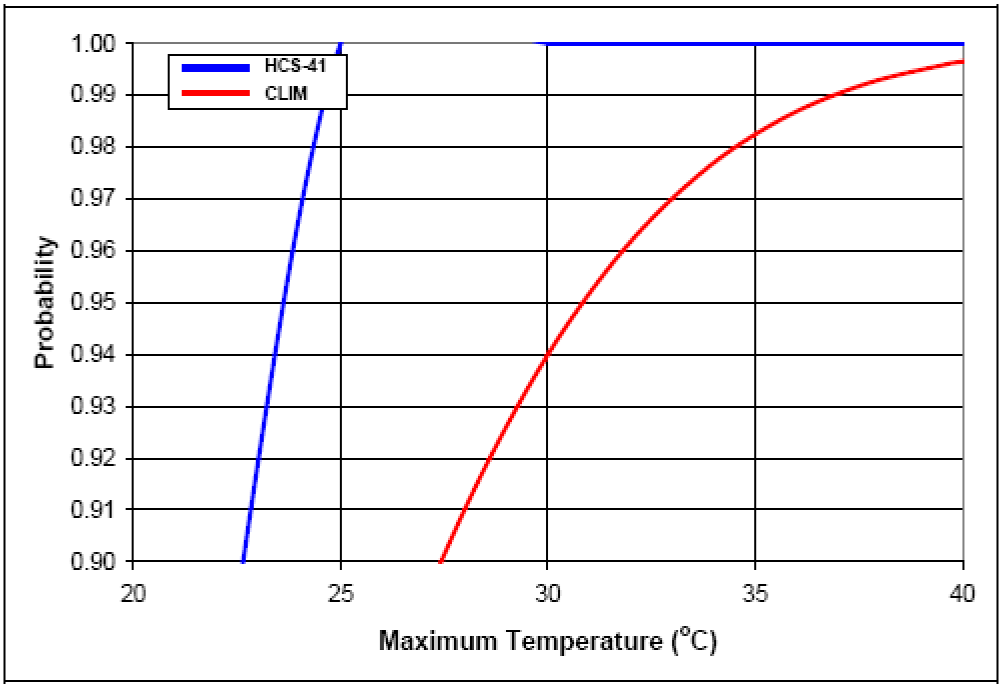

Figure 3: A magnification of the probability distribution from Figure 2

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Table 1: Cumulative hours of exposure and percent of total time of ambient conditions of at least a set temperature over a ten-year period (Source: **CONFIDENTIAL**)

Temperature	Avg. US/Canada Weighted by Area	Avg. U.S/Canada Weighted by Registration	Phoenix	U.S. Worst Case
95F (35C)	124 (0.15%)	571 (0.65%)	9,485 (11%)	11,392 (13%)
105F (40.46C)	0.0 (0%)	44.4 (0.05%)	1,981 (2.3%)	3,310 (3.8%)
115F (46.11C)	0.0 (0%)	0.8 (0%)	14.3 (0.02%)	88.7 (0.1%)

Table 2: Comparison of **CONFIDENTIAL** and CLIM climatic data predictions

Temperature	Avg. U.S/Canada Weighted by Registration	CLIM Data	CLIM Data (Equivalent Periods)
95F (35C)	0.650%	1.5%	0.375%
105F (40.46C)	0.050%	0.35%	0.087%
115F (46.11C)	0.001%	0.035%	0.008%

Table 3: Maximum temperature rise at approximately 35C outdoor temperatures

Company	Container	Dimensions	Max Temp Rise
DfR Solutions	Metal Box	0.16' x 0.16' x 0.16' (~0.01 ft^3)	10C
CONFIDENTIAL	Car Trunk	N/A (~10 ft^3)	20C
PC Manufacturer	Trailer	44.5' x 7.75' x 9' (3100 ft^3)	30C

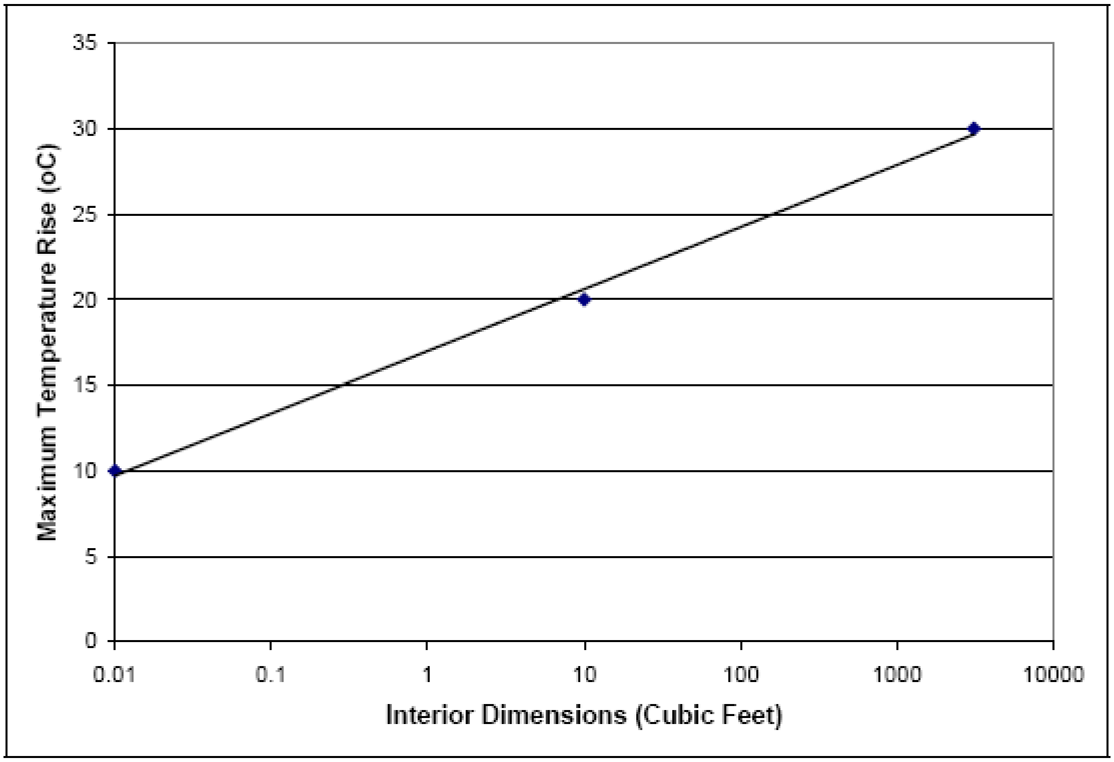

Figure 4: Maximum temperature rise at approximately 35C outdoor temperatures

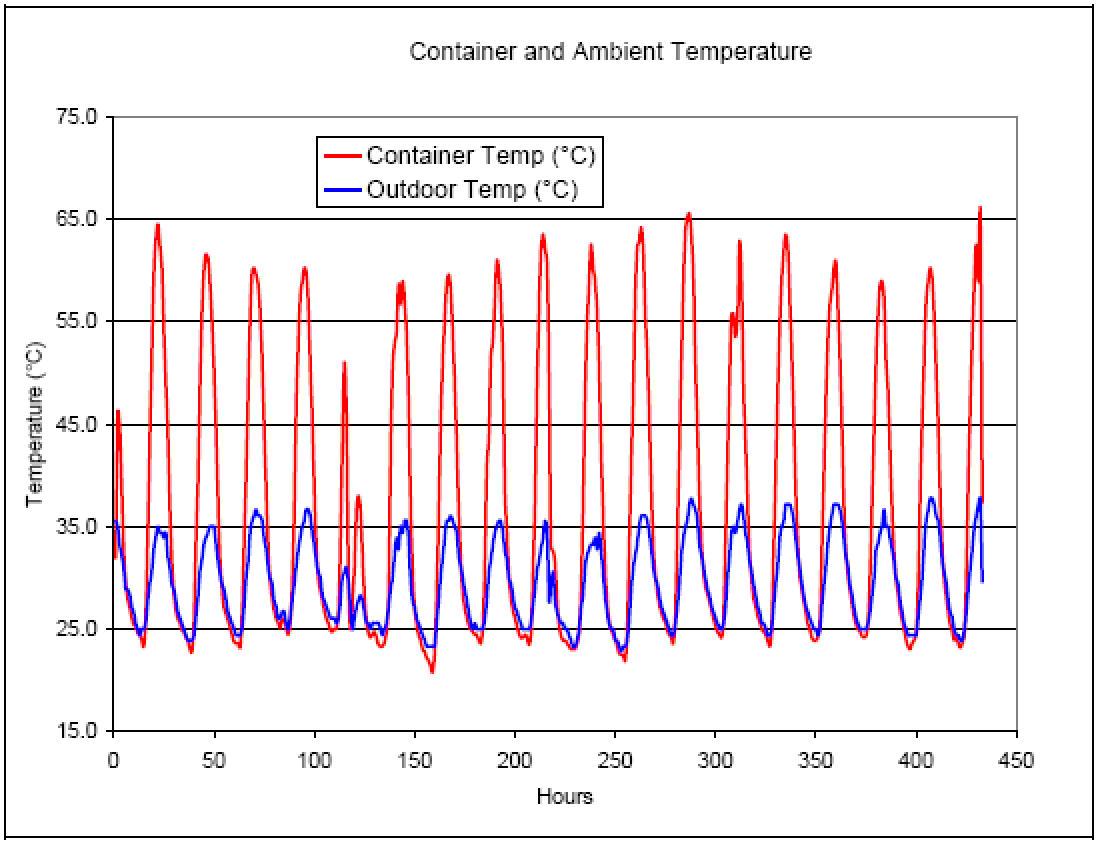

Figure 5: Variation in shipping container temperature as a function of outdoor air temperatures

Table 4: Answer to question 1

Outdoor Temperature	Temperature Rise	Temperature within Outdoor Cabinet	Avg US Hours/Year
35C	20C	55C	30 - 60
40C	25C	65C	5 - 10
45C	30C	65C	0.1 - 1

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