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**Carly Fiorina**
2013 FALL CONFERENCE
KEYNOTE SPEAKER

# IBM'S LEADERSHIP DATA CENTERS

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### *IBM Boulder Command Center*

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# 11 DATA CENTER MYTHS & DESIGN ISSUES

*by Dennis Julian, PE, ATD, DCEP*

Data center design has seen a vast change in approach and priorities. As designs evolve to address energy efficiency and costs, some key points to consider and understand are:

### 1. PUE does not equal electric service size or generator capacity.

Power Usage Effectiveness (PUE) is a measure of the ratio of total data center power divided by the total IT power. PUE that is measured instantaneously is not valid to determine the total electrical power required unless it is measured at the precise peak power usage of the facility. A correctly calculated PUE uses annual averages to account for seasonal variations. It is possible for the PUE to vary from a monthly high of 1.9 to a monthly low of 1.3 (RTU system in the Northeast) with an annual average of 1.4. If the electrical service was designed based on the 1.4 PUE the service and the engine-generator system would be undersized.

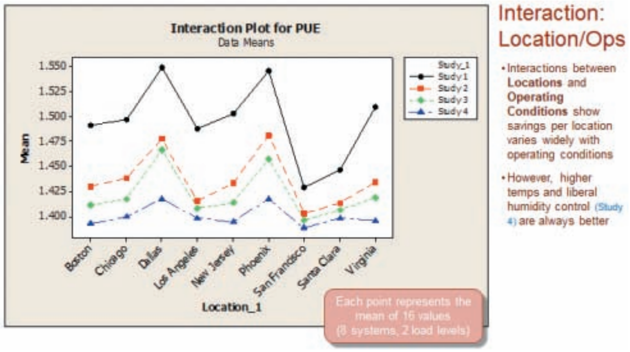
a. Example: Assuming a 1000kW IT load:

- At an average PUE of 1.4 the electrical service and generator system would be sized for 1400kW.
- At the peak PUE of 1.9 the electrical service and generator system would be sized for 1900kW.
- The system would be short 500kW at peak load, undersized by approximately 35%.

### 2. Air economizer is not the optimum system everywhere.

The energy savings obtained depends heavily on the operating temperature and humidity requirements of the computer room and the geographic climate in which the site is located. Roof top units (RTUs) with airside economizer can vary from an annualized PUE of 1.23 in San Francisco, CA to 1.35 in Dallas, TX. Other cooling systems can have lower PUEs varying from 1.18 to 1.31 respectively, for the same locations and operating parameters. Local air pollution and environmental threats need to be assessed and a solution discussed to mitigate the potential risks. The difference in PUE for air economizer systems and closed systems with water side economizers, pumped refrigerant, indirect adiabatic cooling, etc. is slight, the closed system could have a better PUE, and may be offset by the additional risks involved.

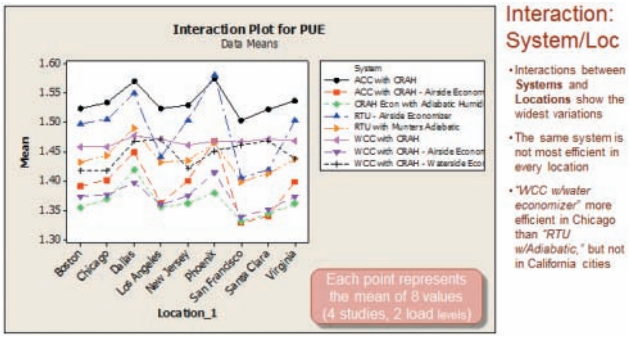
a. Not reflected in the PUEs indicated above, chilled water systems can be designed to further lower the PUE by using warm water temperatures of approximately 55°F - 59°F (13°C - 15°C). This allows the chiller to operate more efficiently and to take advantage of many more economizer hours. To increase efficiency, the redundant air handling units (CRAHs, AHUs, etc) can all be operated thereby reducing the average fan power and increasing the heat rejection at warmer water temperatures. If redundant units are not available or if room humidity needs to be lowered, than the chiller water temperature can be reset to a lower level to provide the additional cooling capacity and dehumidification required. Chillers also allow the use of localized cooling with rear door heat exchangers, or water cooled cabinets which will reduce the total fan power required to cool the space.



Each point represents the mean of 16 values (8 systems, 2 load levels)

Interaction: Location/Ops

- Interactions between **Locations** and **Operating Conditions** show savings per location varies widely with operating conditions
- However, higher temps and liberal humidity control (Study 4) are always better



Each point represents the mean of 8 values (4 studies, 2 load levels)

Interaction: System/Loc

- Interactions between **Systems** and **Locations** show the widest variations
- The same system is not most efficient in every location
- *"WCC w/water economizer"* more efficient in Chicago than *"RTU w/Adiabatic,"* but not in California cities

### 3. Air economizer design and operational issues.

Air economizers introduce a vast quantity of air into the data center. This is different than past designs which typically were closed systems with precision air conditioners maintaining tight restrictions on the recirculating air within the data center. New designs using outdoor air economizers for "free cooling" have brought with them a number of design challenges that require detailed solutions for a successful implementation.

a. Typical data center airflow could be approximately 1.5 room air changes or more per minute.

b. Transitioning to and from economizer means outdoor conditions are reflected indoors quickly and may violate ASHRAE TC9.9 rate of change recommendations of:

- Maximum rate of humidity change is less than 5% RH per hour, and no condensation.
- Maximum rate of temperature change is 5°C/hr (9°F/hr) for data centers employing tape drives and 20°C/hr (36°F /hr) for data centers employing disk drives.

c. Outdoor air contamination concerns including pollen, dusts, leaves, etc require additional and bulky filtering systems which can be expensive and require high maintenance.

d. Smoke brought into the facility from outdoor building or forest fires can activate interior alarm systems and potentially shut down the air handling cooling systems.

e. Air contaminants can be from localized air pollution from people or industries or from environmental events such as forest or building fires.

f. Air borne threats, accidental or targeted. A crash adjacent to the site or a specific terrorist attack on the facility, or an adjacent neighbor, could allow contaminants to enter the facility faster than the system can react, assuming it has sensors to detect that particular threat.

g. Pressurization control is vital. Due to the large volumes of air, slight differences in supply and exhaust systems can result in rooms being over or under pressurized causing roofs to balloon up or walls to move. Damper opening and closing times must be coordinated, air flows must be balanced and controls must be robust. Outdoor air leakage through air handling units must be minimized. Controls need to consider failure scenarios and the system should build in pressure relief, both positive and negative.

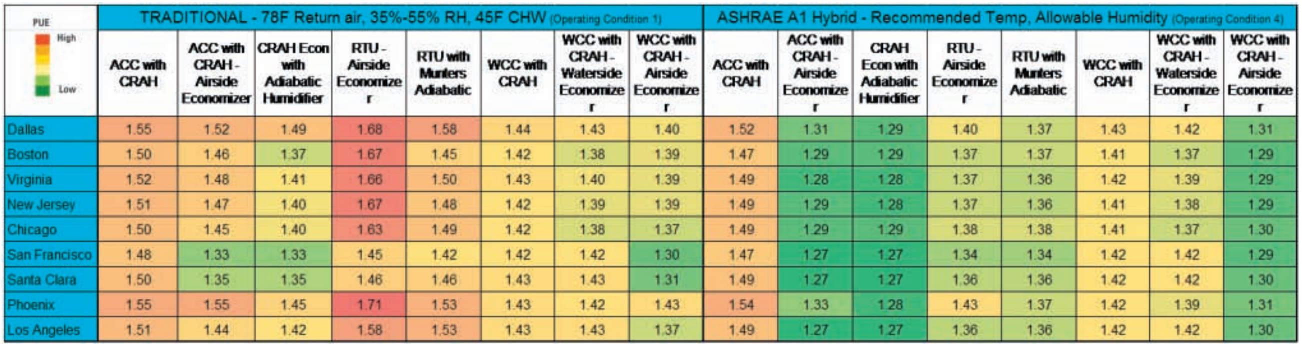
h. Mitigation: Controls and sensors must be provided to respond to these operational threats. Designs must consider these real world risks and provide practical solutions. Theoretically, sensors can detect and systems can respond by closing outdoor dampers but the reality is that these operations take time to occur and at the high air volumes being provided there is little time to react, literally only a few seconds. If sensors are set too sensitive, and react to often, the planned for benefits of air economization may never be obtained.

### 4. The optimum cooling system is not obvious.

In a study comparing multiple system cooling systems in the same geographic location (Virginia) and computer room operating temperatures and humidity levels (ASHRAE recommended temperatures and allowable humidity levels) the following annual PUE values were calculated:

| System | Annual PUE |
|---|---|
| Air cooled chiller (ACC) with CRAH | 1.40 |
| Air cooled chiller (ACC) with CRAH and airside economizer | 1.30 |
| Air cooled chiller (ACC) with CRAH and airside economizer with adiabatic humidifier | 1.27 |
| Roof top unit (RTU) with airside economizer | 1.33 |
| Roof top unit (RTU) with evaporative adiabatic humidifier | 1.30 |
| Water cooled chiller (WCC) with CRAH | 1.38 |
| Water cooled chiller (WCC) with CRAH and waterside economizer | 1.28 |
| CRAC units with pumped refrigerant economizer | 1.25 |

a. A PUE difference of 0.01 for a 1000kW IT load and an electrical equivalent cost of $0.14/kWh equals $12,264 per year.



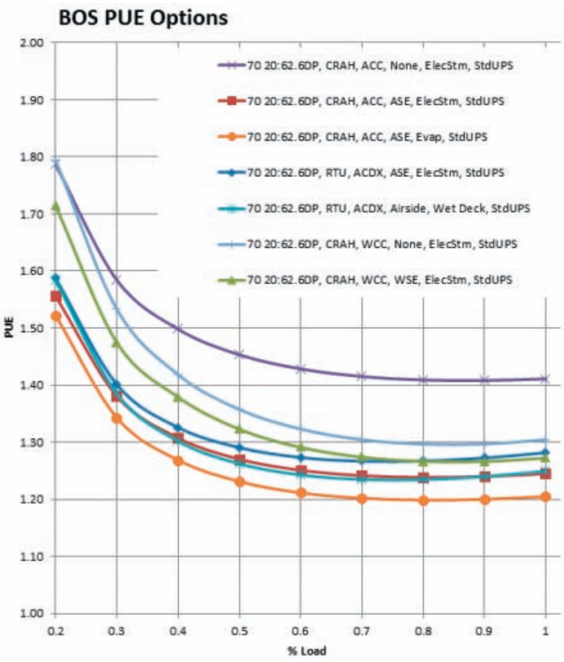
| PUE | TRADITIONAL - 78F Return air, 35%-55% RH, 45F CHW (Operating Condition 1) | | | | | | | | ASHRAE A1 Hybrid - Recommended Temp, Allowable Humidity (Operating Condition 4) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| High<br>Low | ACC with CRAH | ACC with CRAH - Airside Economizer | CRAH Econ with Adiabatic Humidifier | RTU - Airside Economizer | RTU with Munters Adiabatic | WCC with CRAH | WCC with CRAH - Waterside Economizer | WCC with CRAH - Airside Economizer | ACC with CRAH | ACC with CRAH - Airside Economizer | CRAH Econ with Adiabatic Humidifier | RTU - Airside Economizer | RTU with Munters Adiabatic | WCC with CRAH | WCC with CRAH - Waterside Economizer | WCC with CRAH - Airside Economizer |
| Dallas | 1.55 | 1.52 | 1.49 | 1.68 | 1.58 | 1.44 | 1.43 | 1.40 | 1.52 | 1.31 | 1.29 | 1.40 | 1.37 | 1.43 | 1.42 | 1.31 |
| Boston | 1.50 | 1.46 | 1.37 | 1.67 | 1.45 | 1.42 | 1.38 | 1.39 | 1.47 | 1.29 | 1.29 | 1.37 | 1.37 | 1.41 | 1.37 | 1.29 |
| Virginia | 1.52 | 1.48 | 1.41 | 1.66 | 1.50 | 1.43 | 1.40 | 1.39 | 1.49 | 1.28 | 1.28 | 1.37 | 1.36 | 1.42 | 1.39 | 1.29 |
| New Jersey | 1.51 | 1.47 | 1.40 | 1.67 | 1.48 | 1.42 | 1.39 | 1.39 | 1.49 | 1.29 | 1.28 | 1.37 | 1.36 | 1.41 | 1.38 | 1.29 |
| Chicago | 1.50 | 1.45 | 1.40 | 1.63 | 1.49 | 1.42 | 1.38 | 1.37 | 1.49 | 1.29 | 1.29 | 1.38 | 1.38 | 1.41 | 1.37 | 1.30 |
| San Francisco | 1.48 | 1.33 | 1.33 | 1.45 | 1.42 | 1.42 | 1.42 | 1.30 | 1.47 | 1.27 | 1.27 | 1.34 | 1.34 | 1.42 | 1.42 | 1.29 |
| Santa Clara | 1.50 | 1.35 | 1.35 | 1.46 | 1.46 | 1.43 | 1.43 | 1.31 | 1.49 | 1.27 | 1.27 | 1.36 | 1.36 | 1.42 | 1.42 | 1.30 |
| Phoenix | 1.55 | 1.55 | 1.45 | 1.71 | 1.53 | 1.43 | 1.42 | 1.43 | 1.54 | 1.33 | 1.28 | 1.43 | 1.37 | 1.42 | 1.39 | 1.31 |
| Los Angeles | 1.51 | 1.44 | 1.42 | 1.58 | 1.53 | 1.43 | 1.43 | 1.37 | 1.49 | 1.27 | 1.27 | 1.36 | 1.36 | 1.42 | 1.42 | 1.30 |

*Difficult to read but resulting PUE color formatted so that green represents the lowest PUE and red the highest.*

### 5. Conclusions from the PUE study:

a. PUE varies by load. 100% loaded systems tend to be the most efficient.

PUE Variations for Different Systems and Load Levels



b. The major factors effecting PUE are the operating temperatures and humidity levels required in the computer room.

c. Warmer IT equipment input operating temperatures allow maximum economizer hours, higher supply air temperatures and warmer chilled water.

d. Wider humidity limits allow maximum economizer hours, in particular in cold weather with low outdoor humidity and in humid climates.

e. No one HVAC system is the optimum solution in all geographic locations.

### 6. Water cooled chiller ROI may not be better than air cooled chillers.

Water cooled chillers are assumed to have the lowest operating cost. On a kW per ton basis this is typically correct. In a study performed for a Virginia location the following was found:

a. The results of the analysis show that in all years the Total Cost of Ownership (TCO) is highest for the water cooled chiller (WCC) system compared to the air cooled chiller (ACC) options with and without waterside economizer. The WCC system does have the lowest annual energy cost, however this is offset by the higher initial capital costs of the chillers, cooling towers and water storage, and the higher annual operating cost for water, sewer and maintenance required for the WCC system.

b. Highlights of the study:

- 7.2 MW of IT equipment load.
- Operating Conditions: Cold Aisle Temperature Control, 77°F setpoint, 20%-80% RH, Max DP = 62.6°F, chilled water temperature = 59°F.
- 57.8 million gallons of water per year required for cooling tower operation.
- 11.6 million gallons of water dumped to sanitary per year for tower blow down.
- First year TCO is $3.5 million less for air cooled vs water cooled chillers due to initial equipment and water storage costs.
- Tenth year total TCO is $4.6 million less for air cooled vs water cooled chillers.

### 7. Humidity – Relative Humidity (RH) vs Dew Point (DP).

Absolute humidity is the water content of air. Relative humidity, expressed as a percent, measures the current absolute humidity relative to the maximum humidity the air can hold at that temperature.

Relative Humidity varies with temperature for the same quantity of water in the air (absolute humidity). Location of humidity sensors for service level agreements (SLA) are critical. Dew point sensors are not sensitive to hot or cold aisle placement, but RH sensor measurement will vary widely. The same dew point measured in a hot aisle will be different that the same dew point measured in a cold aisle.

a. Recommended ASHRAE limits, based on the inlet of the IT equipment:

- 5.5°C DP to 60% RH and 15°C DP
- 41.9°F DP to 60% RH and 59°F DP

b. Allowable ASHRAE limits, based on the inlet of the IT equipment:

- 20% to 80% RH
- Maximum Dew Point 17˚C (62.6°F)

c. ASHRAE Maximum Rate of Humidity Change:

- Rate of change of humidity is less than 5% RH per hour, and no condensation.

d. The graphic indicates the ASHRAE environmental envelopes for the various classes of electronic equipment (Class A1 is the typical computer room). The curved lines show how relative humidity varies with temperature. The dew point (moisture content) is indicated on the right axis and is constant across the range of temperatures.

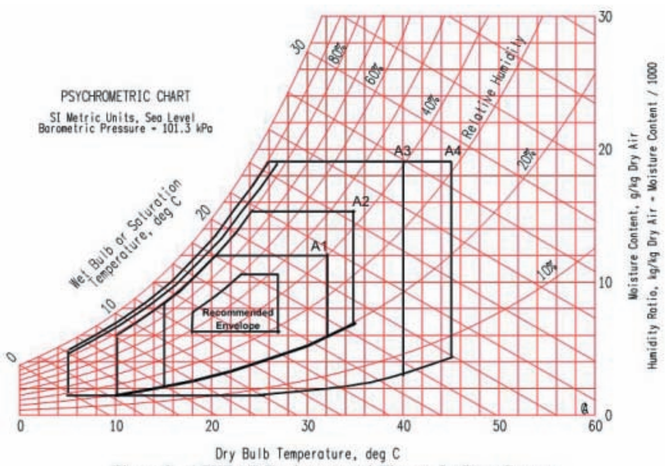


Figure 2. ASHRAE Environmental Classes for Data Centers

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### 8. Fuel oil systems need to be robust, weatherproof, and of a waterproof design if appropriate.

Flooding can occur due to storms, clogs, backups, pipe breaks or other reasons. If tanks are above ground they can and should be designed to operate under water, similar to designs used for underground tanks. Back up alternate fuel system piping with valved connections with power outlets for pumper trucks should be provided to allow temporary emergency fuel to be supplied in case of a fuel system failure. Tanks should be securely tied down to overcome the buoyant effect of fuel oil in water.

### 9. Multiple string batteries designed as a N+1 system should be considered.

This design allows de-energized battery maintenance while the UPS is operational with battery backup thereby minimizing risks.

a. Transformerless UPS systems increase the likelihood of a dangerous ground fault during maintenance, do not isolate the fault from the remainder of the power system and may cause a much larger outage to occur which may affect IT operation.

b. Arc flash considerations may require battery maintenance to occur while the batteries are de-energized.

c. The number and capacity of the strings must be sized correctly so the UPS will operate with one string disconnected. Having multiple VLRA cabinets with individual disconnects does not necessarily allow one of the cabinets to be disconnected while the UPS maintains battery backup protection. The system must be designed to provide enough power and voltage (number of battery cells) to allow the batteries to carry the load with one string disconnected. Typically this would be with less battery protection time, but adequate to support the load and allow time to get to generator power.

### 10. Nitrogen purge systems.

Nitrogen purge systems for preaction sprinklers deal with leaks, corrosion and microbials, by eliminating water vapor and oxygen from the piping system.

a. Even galvanized piping used in pre action systems can develop leaks from corrosion or microbial action. Oxygen and water left in the system after testing or vapor contained in the compressed air in the system can contribute and enhance these corrosion effects. The nitrogen purge system fills the piping with nitrogen eliminating the oxygen and water vapor and therefore minimizing the risk of corrosion. Nitrogen system sensors monitor the nitrogen in the system and purge to eliminate water vapor and oxygen. Use of a nitrogen purge system could allow the use of black iron pipe in lieu of galvanized, due to the reduction in corrosion risk.

### 11. Hot aisle / cold aisle operational issues.

Elevated operating temperatures caused by higher supply air temperatures and better separation of hot and cold air streams leads to operating conditions for devices and materials that may reduce useful life or cause nuisance failures or alarms.

a. Standard smoke detector devices are rated for a maximum ambient of 100°F (38°C).

b. Smoke detectors are available rated for a 120°F (49°C) ambient.

c. Heat detectors rated 135°F (57°C) are rated for a maximum ambient of 100°F (38°C).

d. Heat detectors rated 190°F (88°C) and higher ambient of 120°F (49°C) are available.

e. Lighting fixtures are rated for typical office temperatures. Ambients over 90°F (32°C) will affect light output and life expectancy of the lamps and ballasts.

f. Typical 135°F sprinkler heads are rated for use in a 100°F ambient. Intermediate rated heads at a higher temperature rating are recommended to minimize potential false activations.

g. DX cooling systems using compressors such as rooftop units, CRAC units with condenser water or refrigerant heat rejection systems have limitations on the temperature of the return air they can handle without shutting down. This temperature can be as low as 95°F (35°C).

h. High temperatures in particular when associated with high humidity levels can affect personnel working in the computer room. Regulations restrict the time that can be spent in hot areas. This could affect personnel productivity.

- OSHA (Occupational Safety & Health Administration) Technical Manual Section III, Chapter 4 ISO (International Organization for Standardization) 7243, "Hot environments – Estimation of the heat stress on working man based on WBGT index".

**Average Wet-Bulb Globe Temperature (WBGT)**

The “wet-bulb globe temperature” (WBGT) is an index that measures heat stress in human work environments.

For indoor and outdoor conditions with no solar load, WBGT is calculated as: **WBGT = 0.7*NWB + 0.3*GT**

**NWB** Natural Wet-Bulb Temperature
*NWB is measured by placing a water-soaked wick over the bulb of a mercury thermometer. Evaporation reduces the temperature relative to dry-bulb temperature and is a direct representation of the ease with which a worker can dissipate heat by sweating.*

**GT** Globe Temperature
*For a data center, the dry-bulb temperature can be used in place of GT without compromising accuracy.*

**DB** Dry-Bulb Temperature
*“Dry-bulb” refers to temperature measured using a typical analog or digital thermometer.*

OSHA Technical Manual SECTION III: CHAPTER 4 HEAT STRESS

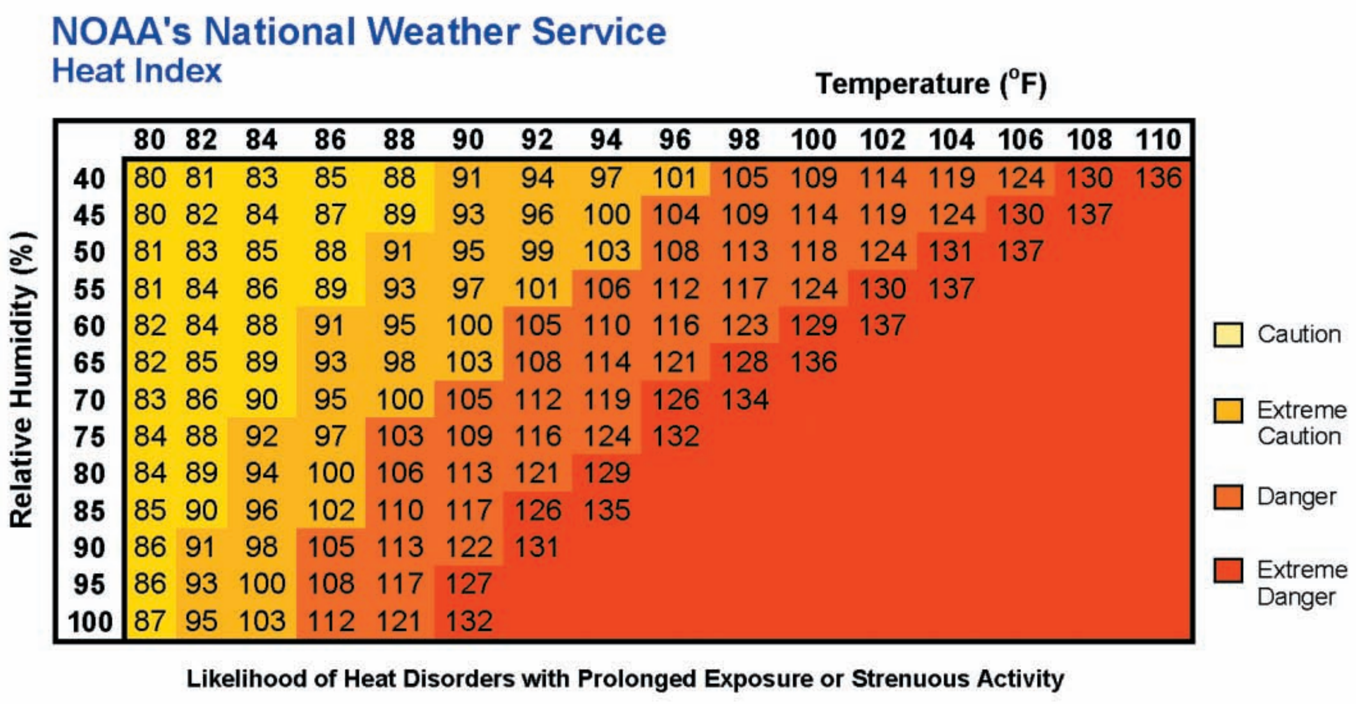
TABLE III: 4-2. PERMISSIBLE HEAT EXPOSURE THRESHOLD LIMIT VALUE

------- Work Load* -------

| Work/rest regimen | Light | Moderate | Heavy |
|---|---|---|---|
| Continuous work | 30.0°C (86°F) | 26.7°C (80°F) | 25.0°C (77°F) |
| 75% Work, 25% rest, each hour | 30.6°C (87°F) | 28.0°C (82°F) | 25.9°C (78°F) |
| 50% Work, 50% rest, each hour | 31.4°C (89°F) | 29.4°C (85°F) | 27.9°C (82°F) |
| 25% Work, 75% rest, each hour | 32.2°C (90°F) | 31.1°C (88°F) | 30.0°C (86°F) |

*Values are in °C and °F, **WBGT**.

These TLV's are based on the assumption that nearly all acclimatized, fully clothed workers with adequate water and salt intake should be able to function effectively under the given working conditions without exceeding a deep body temperature of 38°C (100.4° F).



NOAA's National Weather Service
Heat Index

Temperature (°F)

Relative Humidity (%)

|  | 80 | 82 | 84 | 86 | 88 | 90 | 92 | 94 | 96 | 98 | 100 | 102 | 104 | 106 | 108 | 110 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 40 | 80 | 81 | 83 | 85 | 88 | 91 | 94 | 97 | 101 | 105 | 109 | 114 | 119 | 124 | 130 | 136 |
| 45 | 80 | 82 | 84 | 87 | 89 | 93 | 96 | 100 | 104 | 109 | 114 | 119 | 124 | 130 | 137 |  |
| 50 | 81 | 83 | 85 | 88 | 91 | 95 | 99 | 103 | 108 | 113 | 118 | 124 | 131 | 137 |  |  |
| 55 | 81 | 84 | 86 | 89 | 93 | 97 | 101 | 106 | 112 | 117 | 124 | 130 | 137 |  |  |  |
| 60 | 82 | 84 | 88 | 91 | 95 | 100 | 105 | 110 | 116 | 123 | 129 | 137 |  |  |  |  |
| 65 | 82 | 85 | 89 | 93 | 98 | 103 | 108 | 114 | 121 | 128 | 136 |  |  |  |  |  |
| 70 | 83 | 86 | 90 | 95 | 100 | 105 | 112 | 119 | 126 | 134 |  |  |  |  |  |  |
| 75 | 84 | 88 | 92 | 97 | 103 | 109 | 116 | 124 | 132 |  |  |  |  |  |  |  |
| 80 | 84 | 89 | 94 | 100 | 106 | 113 | 121 | 129 |  |  |  |  |  |  |  |  |
| 85 | 85 | 90 | 96 | 102 | 110 | 117 | 126 | 135 |  |  |  |  |  |  |  |  |
| 90 | 86 | 91 | 98 | 105 | 113 | 122 | 131 |  |  |  |  |  |  |  |  |  |
| 95 | 86 | 93 | 100 | 108 | 117 | 127 |  |  |  |  |  |  |  |  |  |  |
| 100 | 87 | 95 | 103 | 112 | 121 | 132 |  |  |  |  |  |  |  |  |  |  |

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

i. Transformers are designed to operate in maximum room ambient temperatures of 104°F (40°C), with an average room ambient temperature not to exceed 86°F (30°C) in accordance with NEMA standards. Ambient temperatures above these values over a 24-hour period require either a larger KVA rating or a special low temperature rise transformer.

j. Electrical equipment, including panelboards, RPPs, and circuit breakers are designed to operate in a maximum 104°F (40°C) ambient. This includes the temperature rise within the equipment due to internally generated heat rise. Locating equipment in a 104°F (40°C) ambient will lead to internal temperatures within the equipment that exceed the ratings.

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