Effect of Rooftop Exposure on Conduit Ambient Temperatures

COOL ROOF RATING COUNCIL

June 9,2011

Reno Nevada

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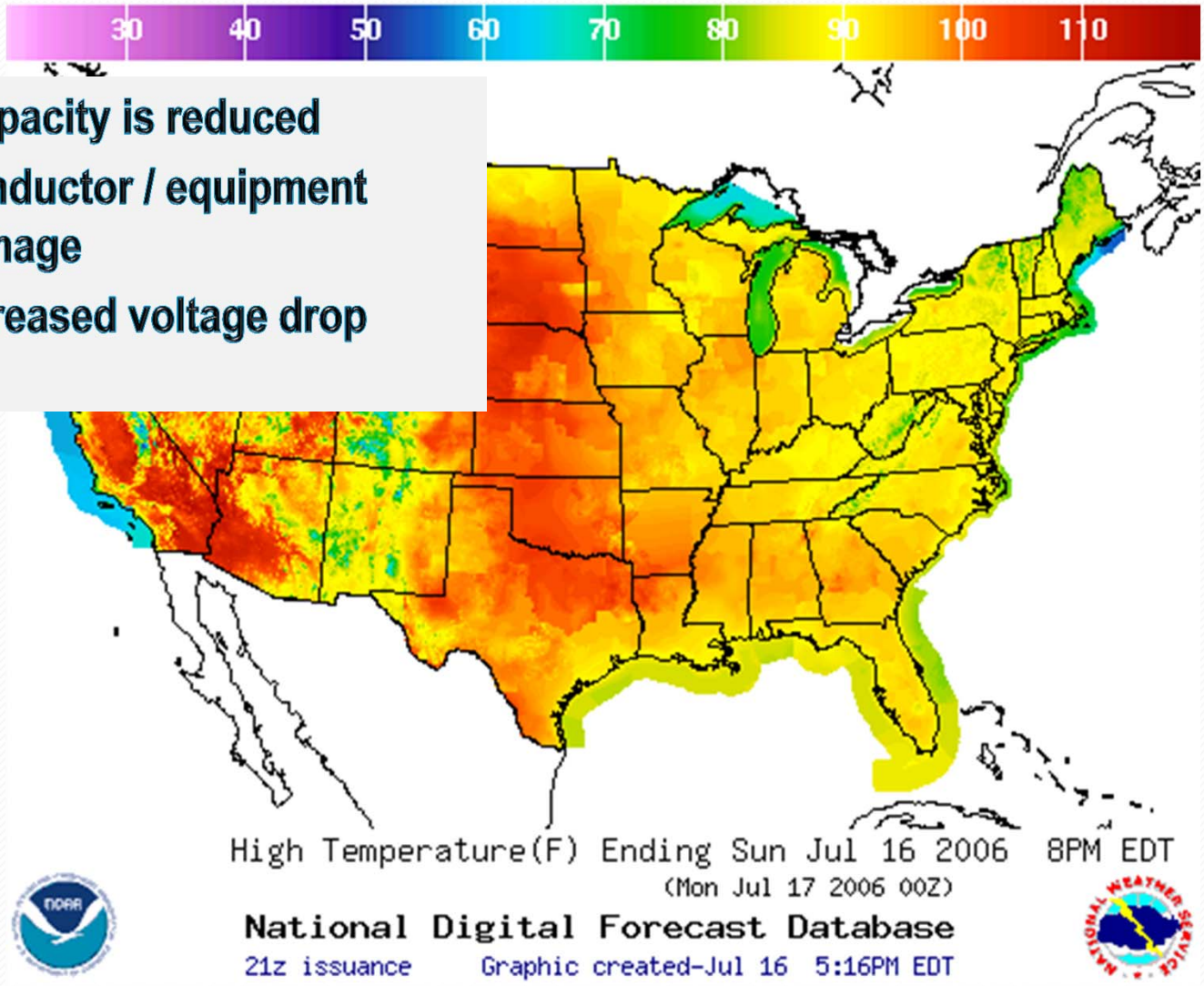
TLCS Inc.

How does sunlight affect electrical conductors in conduits exposed to direct sunlight?

When electrical conductors operate in high ambient temperature environments…

- Ampacity is reduced
- Conductor / equipment damage
- Increased voltage drop



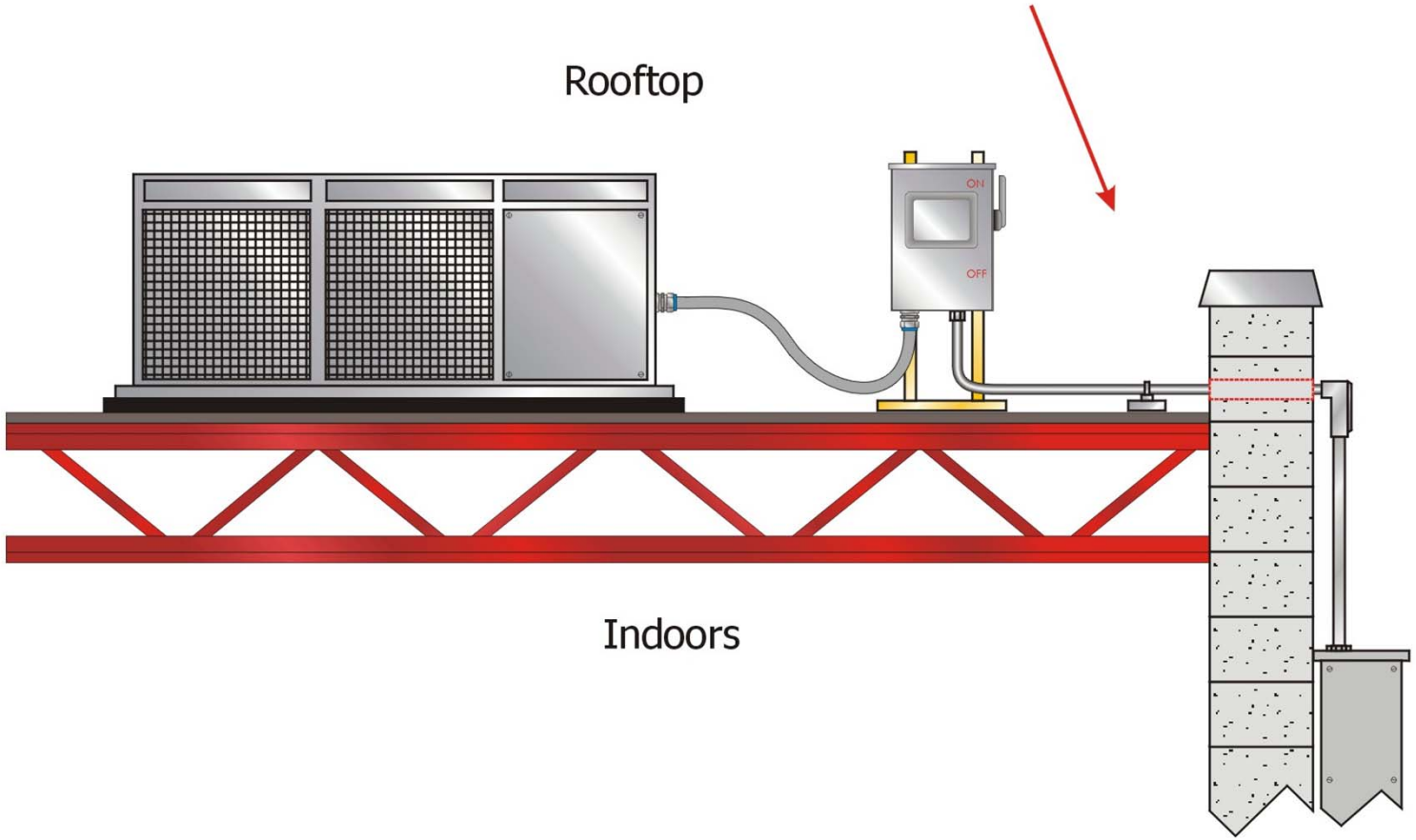
NEC Covers Ambient Temperature Correction

NEC 310.10

Temperature Limitation of Conductors. No conductor shall be used in such a manner that its operating temperature exceeds that designated for the type of insulated conductor involved.

310.10 Temperature Limitation of Conductors

Sunlight can cause temperature rise in conductors above ambient on which their ampacity is based where exposed to the direct rays of the sun



NEC Table 310.16

Table 310.16 Allowable Ampacities of Insulated Conductors Rated 0 Through 2000 Volts, 60°C Through 90°C (140°F Through 194°F), Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)

	Temperature Rating of Conductor (See Table 310.13.)						
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
Size AWG or kcmil	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Size AWG or kcmil
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18	—	—	14	—	—	—	—
16	—	—	18	—	—	—	—
14*	20	20	25	—	—	—	—
12*	25	25	30	20	20	25	12*
10*	30	35	40	25	30	35	10*
8	40	50	55	30	40	45	8
6	55	65	75	40	50	60	6
4	70	85	95	55	65	75	4
3	85	100	110	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	150	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250
300	240	285	320	190	230	255	300
350	260	310	350	210	250	280	350
400	280	335	380	225	270	305	400
500	320	380	430	260	310	350	500
600	355	420	475	285	340	385	600
700	385	460	520	310	375	420	700
750	400	475	535	320	385	435	750
800	410	490	555	330	395	450	800
900	435	520	585	355	425	480	900
1000	455	545	615	375	445	500	1000
1250	495	590	665	405	485	545	1250
1500	520	625	705	435	520	585	1500
1750	545	650	735	455	545	615	1750
2000	560	665	750	470	560	630	2000
	CORRECTION FACTORS						
Ambient Temp. (°C)	For ambient temperatures other than 30°C (86°F), multiply the allowable ampacities shown above by the appropriate factor shown below.						Ambient Temp. (°F)
21–25	1.08	1.05	1.04	1.08	1.05	1.04	70–77
26–30	1.00	1.00	1.00	1.00	1.00	1.00	78–86
31–35	0.91	0.94	0.96	0.91	0.94	0.96	87–95
36–40	0.82	0.88	0.91	0.82	0.88	0.91	96–104
41–45	0.71	0.82	0.87	0.71	0.82	0.87	105–113
46–50	0.58	0.75	0.82	0.58	0.75	0.82	114–122
51–55	0.41	0.67	0.76	0.41	0.67	0.76	123–131
56–60	—	0.58	0.71	—	0.58	0.71	132–140
61–70	—	0.33	0.58	—	0.33	0.58	141–158
71–80	—	—	0.41	—	—	0.41	159–176

* See 240.4(D).

Temperature correction is required, but usually ignored

Data did not exist to allow:

- Engineers and contractors to choose an appropriate temperature for correction.
- Inspectors to effectively enforce NEC (310.10)

Effect of Rooftop Exposure On Conduit Ambient Temperatures

Ambient Temperature Correction

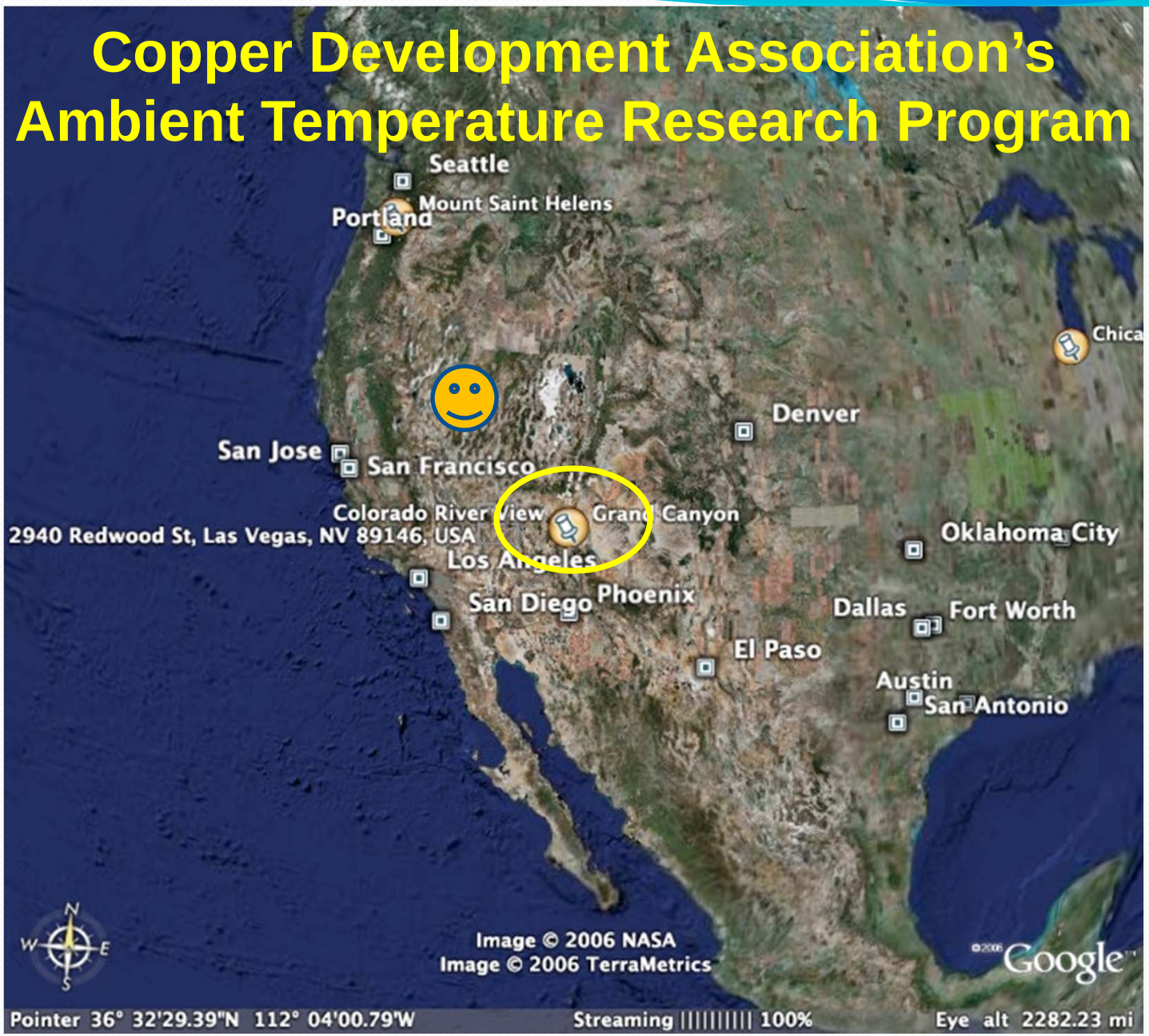
CDA Research Program

In 2002, CDA Launched:

Elevated
Ambient
Temperature
Study

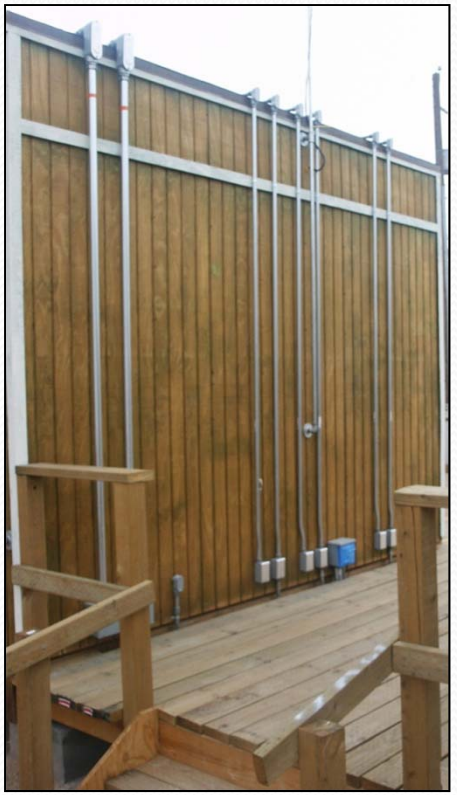
Experiments to determine the extent of heating in copper wires in areas exposed to solar radiation…

Copper Development Association's Ambient Temperature Research Program



Residential and Commercial Buildings

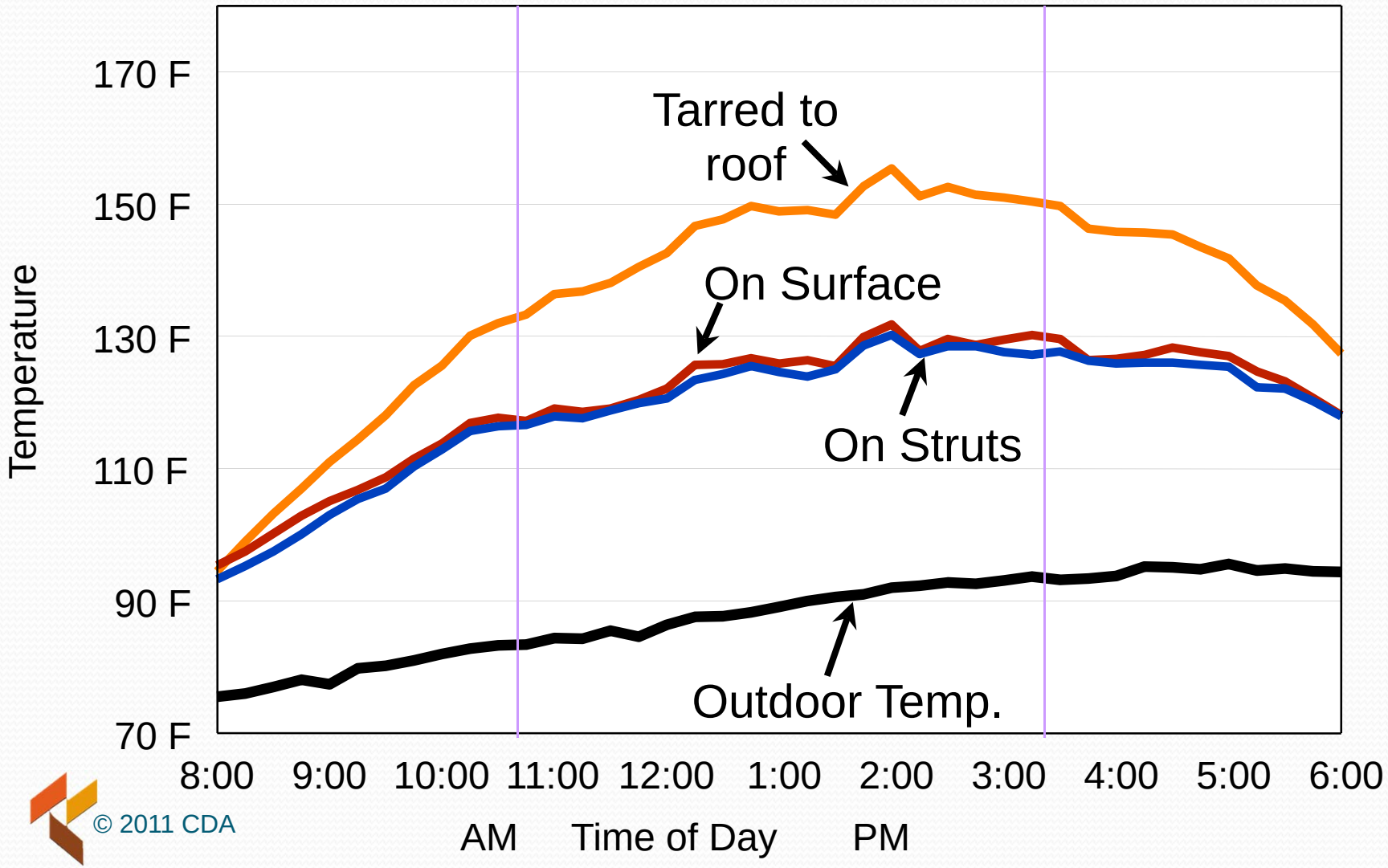
Rooftops and exterior walls



Rooftop temps considerably higher than outdoor temps…

Temperatures of 12 AWG Wires in EMT Compared to Outdoor Temperature

May 20, 2003

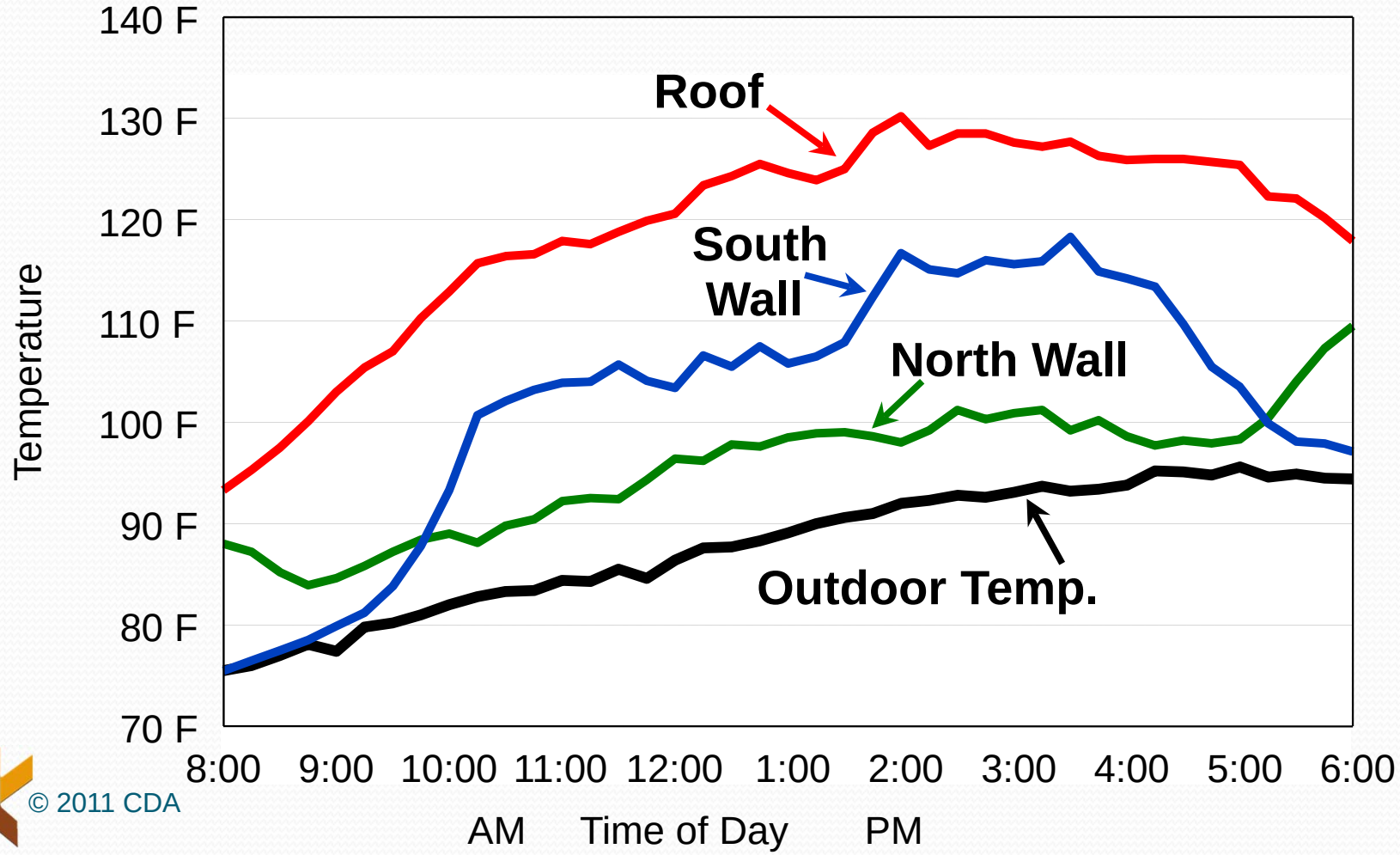


…and rooftop temps considerably higher than outdoor wall temps

Temperature Comparisons

12 AWG in EMT on Roof vs. South and North Walls

May 20, 2003

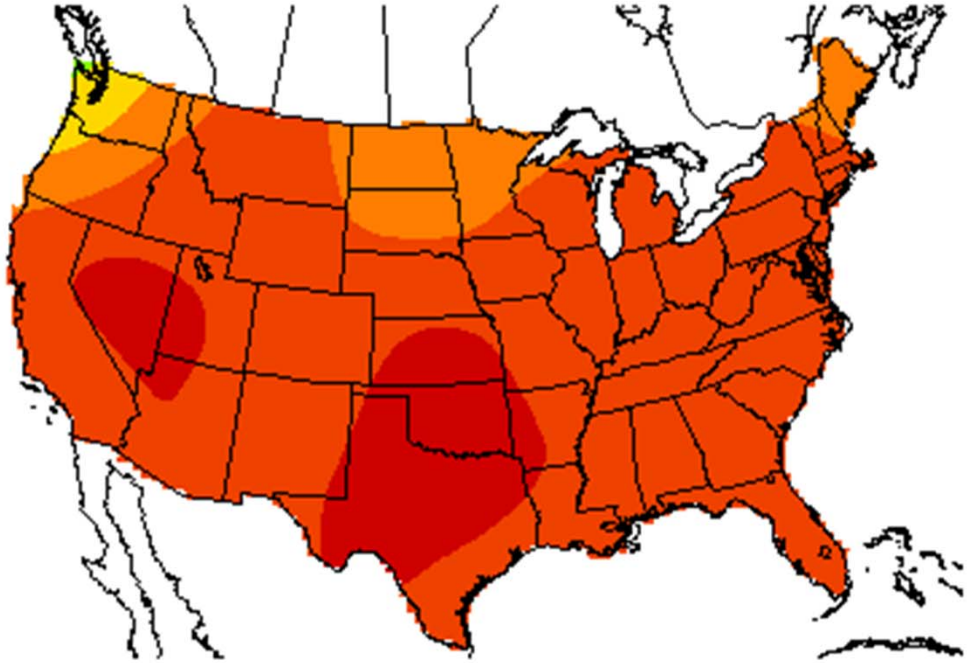


Why Las Vegas?

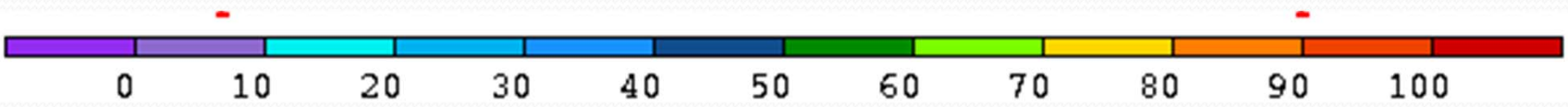
Outdoor Temperatures

- LV summer temps match summer temps in Southwestern U.S. state (incl. CA, AZ, NM, TX, NV)
- Moderate temps in Las Vegas in spring and fall replicate summer temperatures in remainder of country

SUNDAY JULY 16, 2006



Maximum Temperature



Average April and October Temperatures in Las Vegas….

(deg F)	Average Daily Maximum Temperatures												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Au				ec	Year
PHOENIX	65.8	70.7	75.6	84.6	93.6	103.5	106.0	103				.2	85.8
HONOLULU	80.1	80.4	81.7	82.8	84.7	86.5	87.4	88				.1	84.4
MIAMI	75.2	76.5	79.2	82.4	85.3	87.6	89.1	89				.6	82.8
TUCSON	63.9	67.8	72.9	81.1	90.0	99.7	99.3	96.				.2	82.2
TAMPA	69.8	71.4	76.6	81.7	87.3	89.4	90.1	90.1	89.1	84.4	77.7	72.1	81.7
LAS VEGAS	57.4	63.3	68.7	77.5	87.8	100.2	106.0	103.3	94.6	82.0	67.5	57.6	80.4
JACKSONVILLE	64.2	66.9	73.0	79.2	84.7	89.2	91.4	90.7	87.3	80.2	73.6	66.7	79.0
HOUSTON	61.0	6				90.1	92.7	92.5	88.3	81.7	72.3	64.8	78.6
PORT ARTHUR	60.3	6				89.4	91.9	91.8	87.3	80.2	71.2	64.2	77.9
BAKERSFIELD	56.8	6				92.5	98.4	96.6	90.1	80.8	66.7	56.5	77.7
NEW ORLEANS	60.8	6				89.2	90.7	90.1	86.5	79.3	71.1	64.2	77.5
SAVANNAH	59.7	6				88.9	91.0	89.8	85.3	77.5	70.0	62.2	76.5
FORT WORTH	54.1	58.8	67.8	76.3	82.9	91.9	96.4	96.3	87.8	78.4	66.7	57.6	76.3
CHARLESTON	57.7	61.0	68.5	75.7	82.8	87.6	90.1	89.1	84.9	77.2	69.4	61.5	75.6
SACRAMENTO	52.7	60.1	64.0	71.1	80.2	87.8	93.2	92.1	87.3	77.9	63.1	52.7	73.6
BIRMINGHAM	51.6	56.8	66.0	74.7	81.0	87.4	90.0	89.1	83.8	74.7	64.6	55.8	73.0
LITTLE ROCK	48.9	54.0	64.0	73.4	81.3	89.2	92.5	91.4	84.6	75.0	62.8	52.5	72.5
ATLANTA	50.4	55.0	64.2	72.7	79.5	85.8	88.0	87.1	81.9	72.7	63.3	54.0	71.2
Tulsa	45.3	51.1	62.1	73.0	79.7	87.6	93.7	92.5	83.7	73.8	60.3	48.7	71.1
SAN DIEGO	65.8	66.6	66.4	68.4	69.1	71.6	76.3	77.7	77.2	74.7	70.0	66.0	70.9
LOS ANGELES	65.7	65.8	65.5	67.5	69.1	72.0	75.4	76.6	76.6	74.5	70.3	65.8	70.3
ALBUQUERQUE	46.8	53.4	61.3	70.9	79.7	90.0	92.5	89.1	81.9	71.1	57.4	47.5	70.2
RALEIGH	48.9	52.5	62.1	71.8	78.6	84.9	88.0	86.7	81.1	71.6	62.6	52.7	70.2
NASHVILLE	45.9	50.7	61.2	70.9	78.8	86.5	89.4	88.3	82.6	72.5	60.4	50.2	69.8
RICHMOND	45.7	49.3	59.5	70.0	77.7	85.1	88.3	87.1	81.0	70.7	61.3	50.2	68.7
NORFOLK	47.3	49.6	57.9	66.9	75.4	82.9	86.4	85.1	79.5	69.4	61.2	52.2	67.8
RENO	45.1	51.6	56.3	63.7	72.9	83.1	91.9	89.6	79.5	68.5	53.8	45.5	66.7
ST. LOUIS	37.8	42.6	54.7	66.9	76.1	85.3	89.2	87.3	79.9	68.5	54.7	41.7	65.5
SAN FRANCISCO	55.6	59.4	60.8	63.9	66.6	70.3	71.6	72.3	73.6	70.2	62.4	56.1	65.1

OCT 82.0

APR 77.5

Effect of Rooftop Exposure On Conduit Ambient Temperatures

Ambient Temperature Correction

CDA Research Program

Solar Radiation

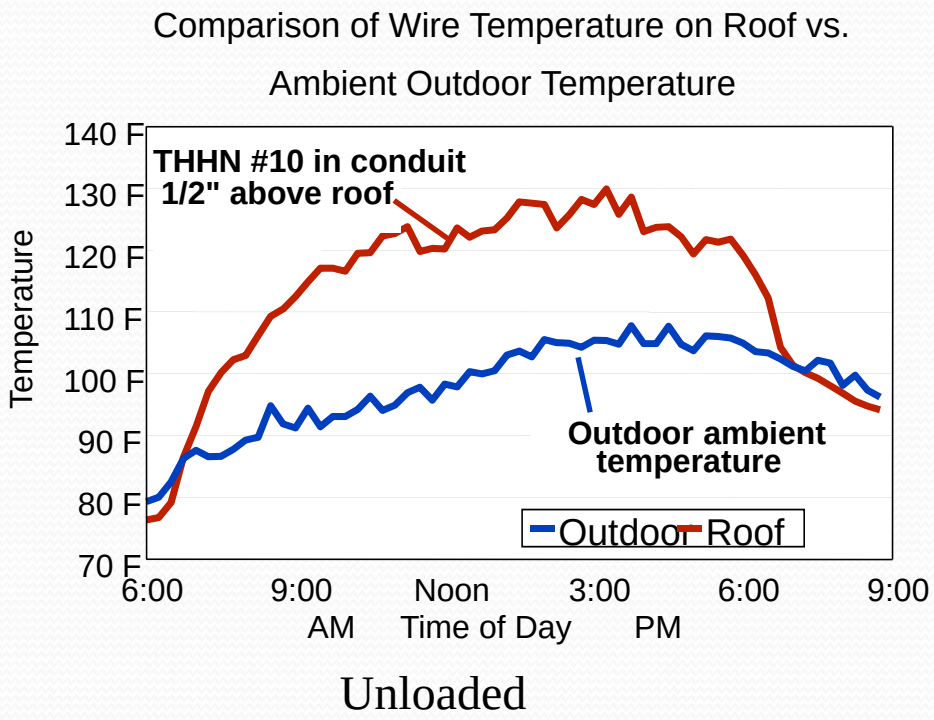
Why Las Vegas?

Solar Radiation

- In Summer, Las Vegas has similar solar radiation to other Southwestern and Western states.
- In Spring and Fall, Las Vegas solar radiation matches Summer solar intensities in most of the U.S.
- Las Vegas has high number of ‘clear days’ to conduct research

Temperature Rise From Solar Effect

Phase I 2002
(9-Conduits)



Unloaded

THHN #10 in conduit

1/2" above roof

Phase II Solar Gain Research

(30-Conduits)

2003

2005 NEC

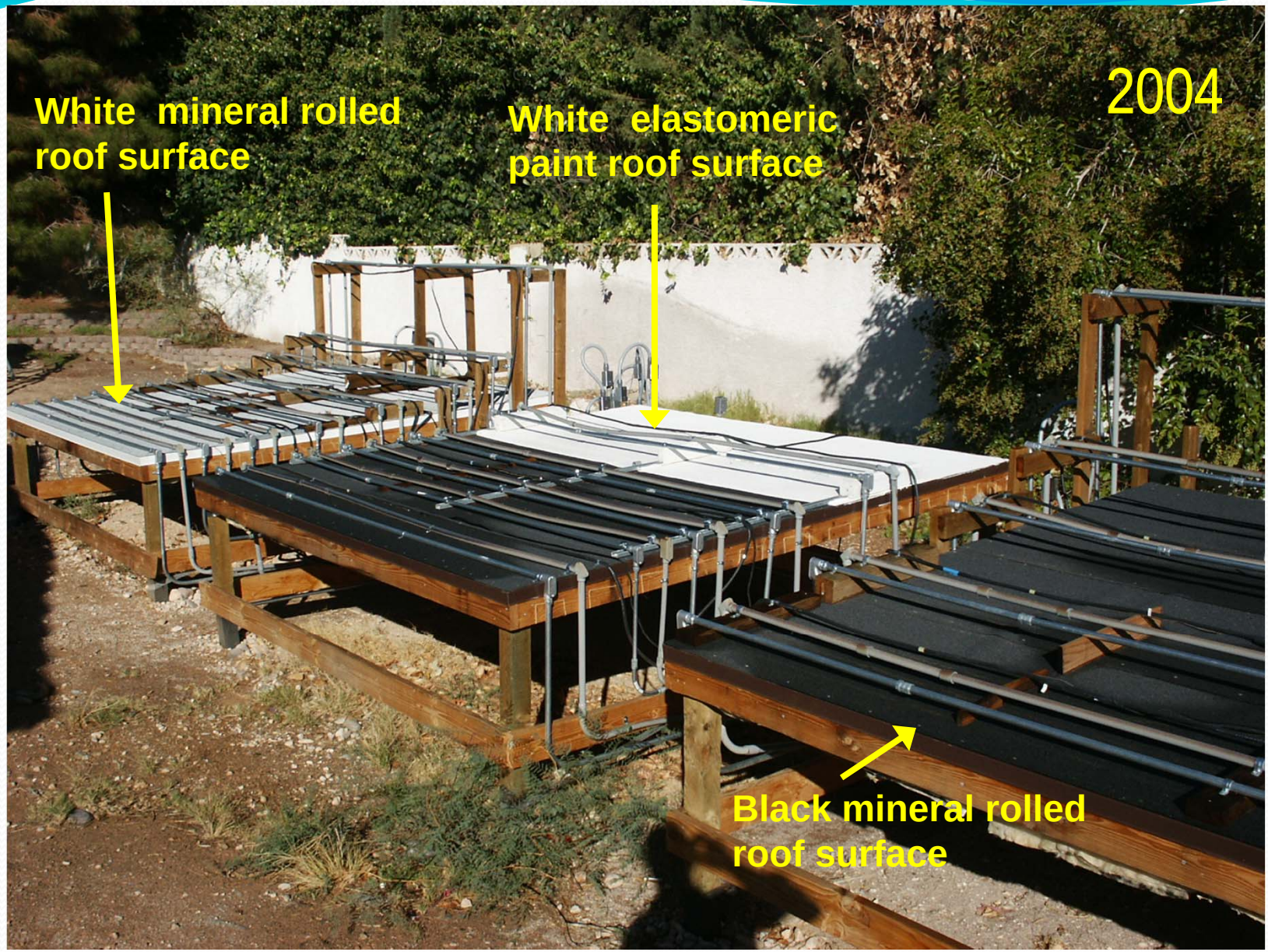
- Added a FPN suggesting adding 17 C (30 F) to ambient temperature
- Panel wanted more data
  - Heights above roof
  - Color of roofs

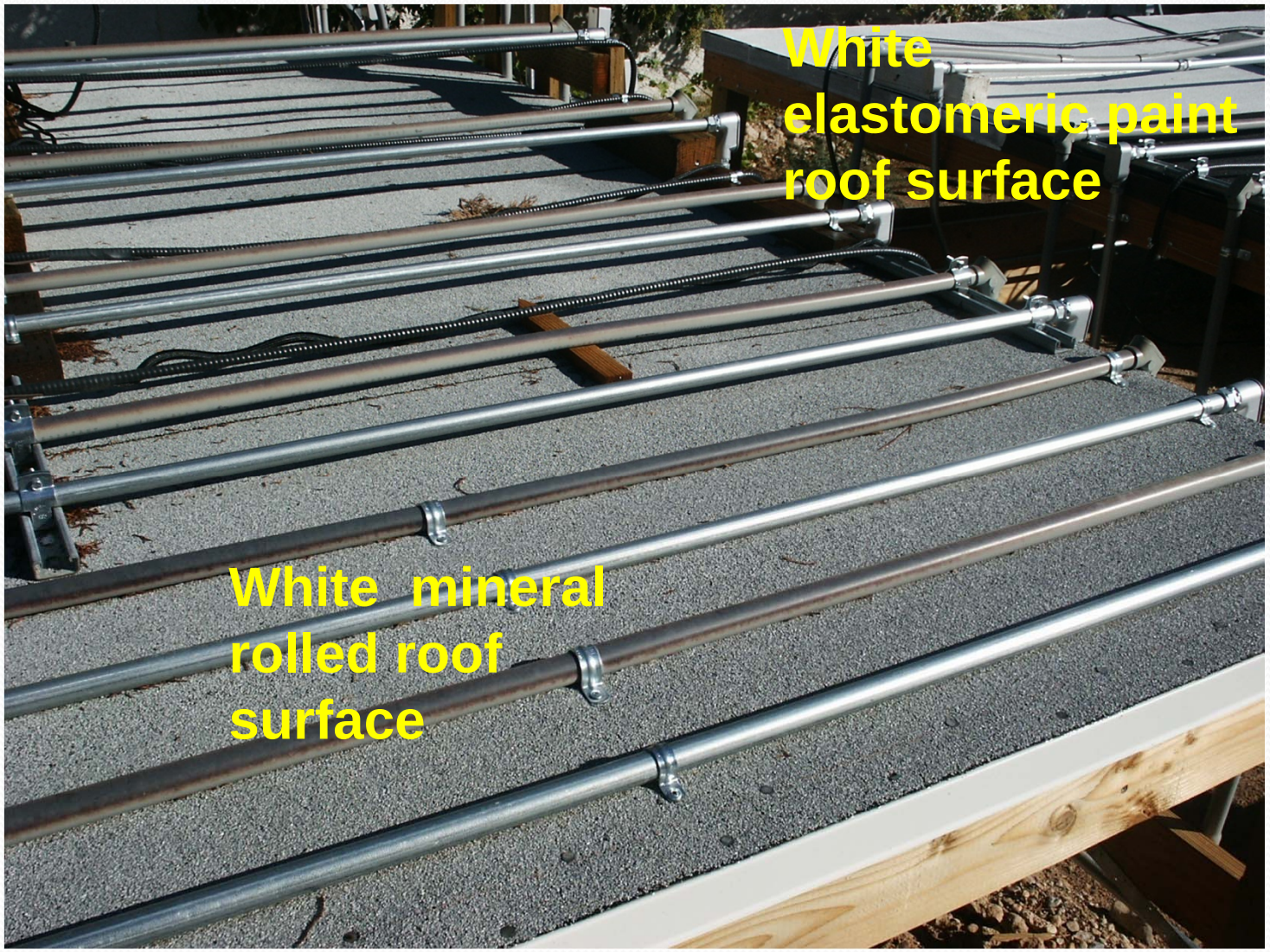
Effect of Rooftop Exposure On Conduit Ambient Temperatures

- Expanded research
  - 3 roof colors
  - Varied heights
  - EMT, RNC, MC

Solar Experiment Research Parameters

- Types of Conduit/Cable
  - EMT, RNC, MC
- Distance above roof
  - On roof
  - 5/8 inch
  - 1-1/2 inch
  - 3.5 inch
  - 6 inch
  - 12 inch
  - 36 inch
- Roof Colors
  - Black mineral rolled roof surface
  - White mineral rolled roof surface
  - White elastomeric paint roof surface
- Unloaded
- Range of:
  - Outdoor temperatures
  - Solar radiation intensities


2004
White mineral rolled roof surface
White elastomeric paint roof surface
Black mineral rolled roof surface

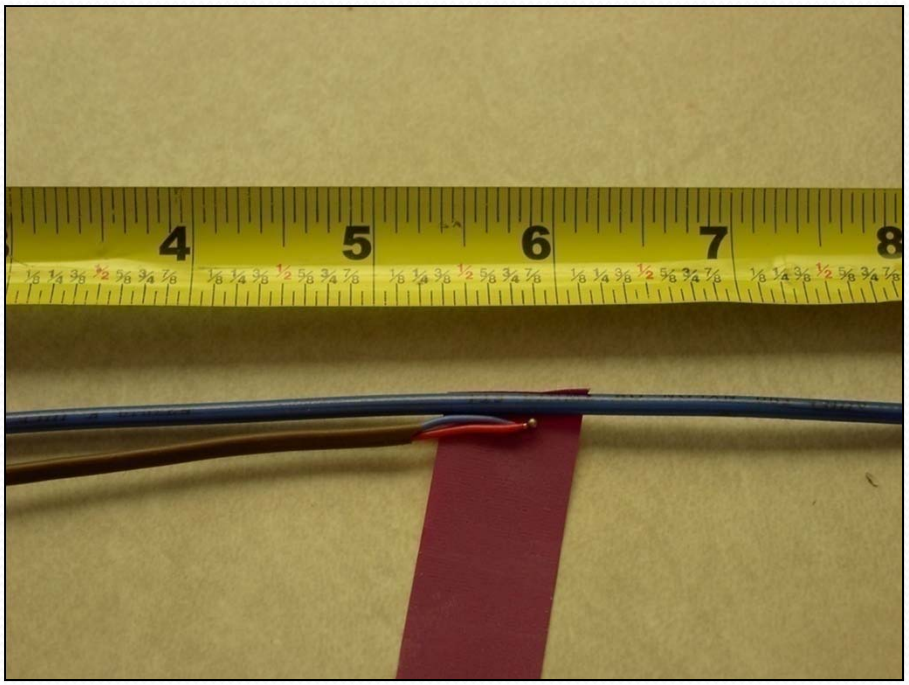

White elastomeric paint roof surface
White mineral rolled roof surface

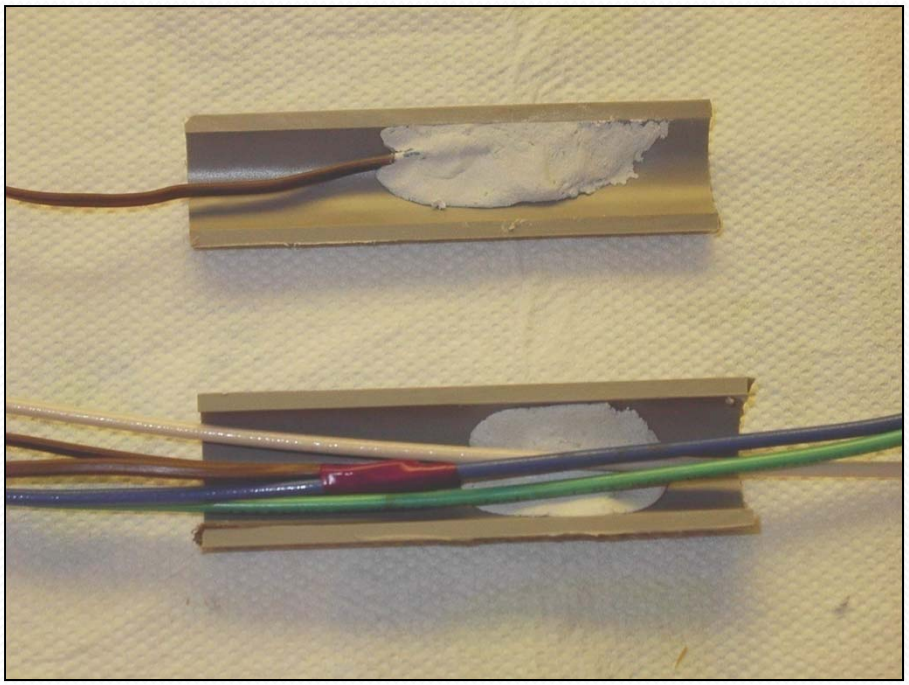
2004

36-inch **12-inch** **6-inch** **3.5 inch** **1.5 inch**

(85 Conduits/Cables)

Ambient temperature measurements are made on insulation of conductor inside conduit

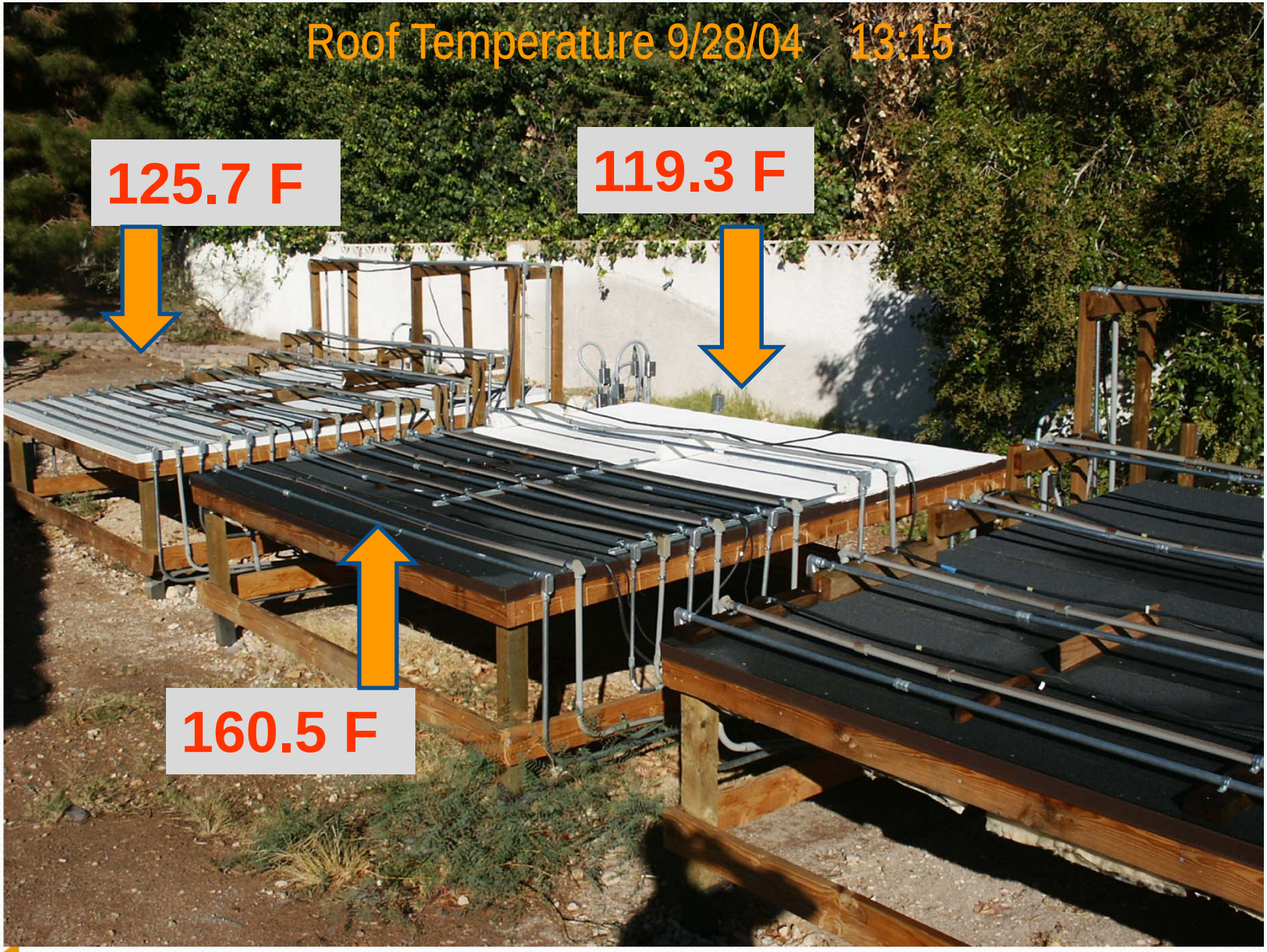




Effect of Rooftop Exposure On Conduit Ambient Temperatures

- Ambient Temperature Correction
- CDA Research Program
- Solar Radiation
- Expanded research
- Research Findings

	Roof Temperatures vs. Outside Ambient Temperature						
Sept. 28th		**WWRD**		**BERD**		**WMRD**	
		Roof itself		Roof itself		Roof	
	Avg.	WHITE		BLACK		White	
	Ambient	West		East		Middle	
	Outdoor	Roof	Differential*	Roof	Differential*	Roof	Differential*
	Temp	In Shingle	WWRD	In shingle	BERD	In shingle	WMRD
11:00	**88.0**	120.2	**32.2**	161.9	**73.9**	112.3	**24.3**
11:15	88.1	119.5	31.4	161.9	73.8	112.9	24.8
11:30	87.5	118.8	31.3	159.0	71.5	113.9	26.4
11:45	88.5	118.4	29.9	153.2	64.7	112.2	23.7
12:00	87.9	118.1	30.2	154.2	66.3	112.6	24.7
12:15	88.2	116.5	28.3	148.3	60.1	110.0	21.8
12:30	89.5	121.6	32.1	159.2	69.7	116.0	26.5
12:45	89.1	121.7	32.6	159.1	70.0	116.5	27.4
13:00	91.0	123.5	32.5	159.7	68.7	116.9	25.9
13:15	92.0	125.7	**33.7**	160.5	**68.5**	119.3	**27.3**
13:30	91.8	123.8	32.0	155.4	63.6	116.3	24.5
13:45	91.8	122.5	30.7	150.7	58.9	114.4	22.6
14:00	92.5	125.9	33.4	157.5	65.0	118.0	25.5
14:15	92.3	125.0	32.7	156.4	64.1	117.1	24.8
14:30	92.2	123.3	31.1	153.2	61.0	116.1	23.9
14:45	91.9	120.5	28.6	149.0	57.1	114.3	22.4
15:00	92.1	119.5	27.4	146.8	54.7	112.3	20.2



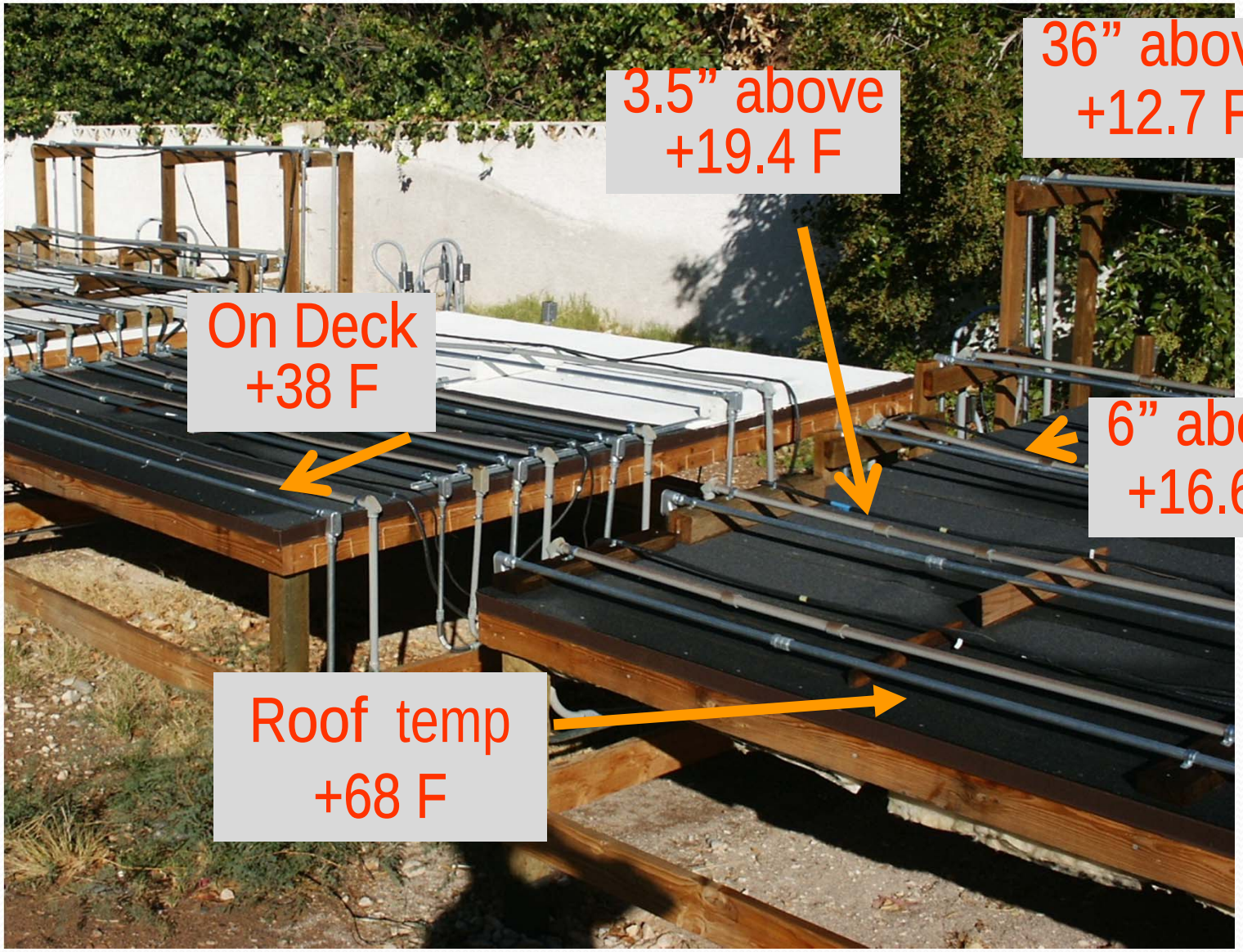
Outdoor Temp = 92 F

Temperature Differential vs. Outside Ambient (92F)

Temps inside EMT Conduit - measured on wire insulation

9/28/04 13:15	Black rolled mineral	White rolled mineral	White painted elastomeric
Roof temp.	68.5	33.7	27.3
On Deck			
3.5” above			
6” above			
36” above			

Temperature Differential vs. Outside Ambient (92F)



Temperature Differential vs. Outside Ambient (92F)

Temps inside EMT Conduit - measured on wire insulation.

9/28/04 13:15	Black rolled mineral	White rolled mineral	White painted elastomeric
Roof temp.	68.5	33.7	27.3
On Deck	38		
3.5” above	19.4		
6” above	16.6		
36” above	12.7		

Temperature Differential vs. Outside Ambient (92F)

Temps inside EMT Conduit - measured on wire insulation.

9/28/04 13:15	Black rolled mineral	White rolled mineral	White painted elastomeric
Roof temp.	68.5	33.7	27.3
On Deck	38	34.2	
3.5” above	19.4	23.1	
6” above	16.6	21.9	
36” above	12.7	15.6	

Temperature Differential vs. Outside Ambient (92F)

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On Deck	38	34.2	
3.5” above	19.4	23	34.1
6” above	16.6	21.9	
36” above	12.7	15.6	

Temperature rise of conductors is consistent over wide range of outdoor temperatures!

Example:	1	2	3	4	5	6	7	8	9	10
Outdoor Temp:	57º F	60º F	68º F	72º F	75º F	86º F	97º F	101º F	109º F	116º F
Day of reading:	31-Jan	31-Mar	22-Jan	14-Apr	15-Apr	12-Jun	21-May	22-May	16-Jul	17-Jul
Time of reading:	11:30	12:00	12:15	1:00	1:00	12:00	12:30	2:00	12:45	2:15
				Temperature Differentials*						
ON roof surface	57º F	65º F	53º F	70º F	63º F	65º F	70º F	65º F	65º F	64º F
5/8" above roof	42º F	47º F	37º F	51º F	43º F	45º F	48º F	46º F	46º F	43º F
1.5" above roof	34º F	37º F	27º F	41º F	32º F	36º F	38º F	33º F	38º F	36º F
3.5" above roof	32º F	35º F	25º F	38º F	31º F	35º F	37º F	33º F	36º F	32º F
6" above roof	30º F	33º F	23º F	34º F	28º F	31º F	33º F	29º F	31º F	26º F
12" above roof	28º F	30º F	20º F	31º F	26º F	29º F	30º F	27º F	29º F	24º F
36" above roof	24º F	26º F	18º F	27º F	23º F	25º F	26º F	24º F	26º F	22º F

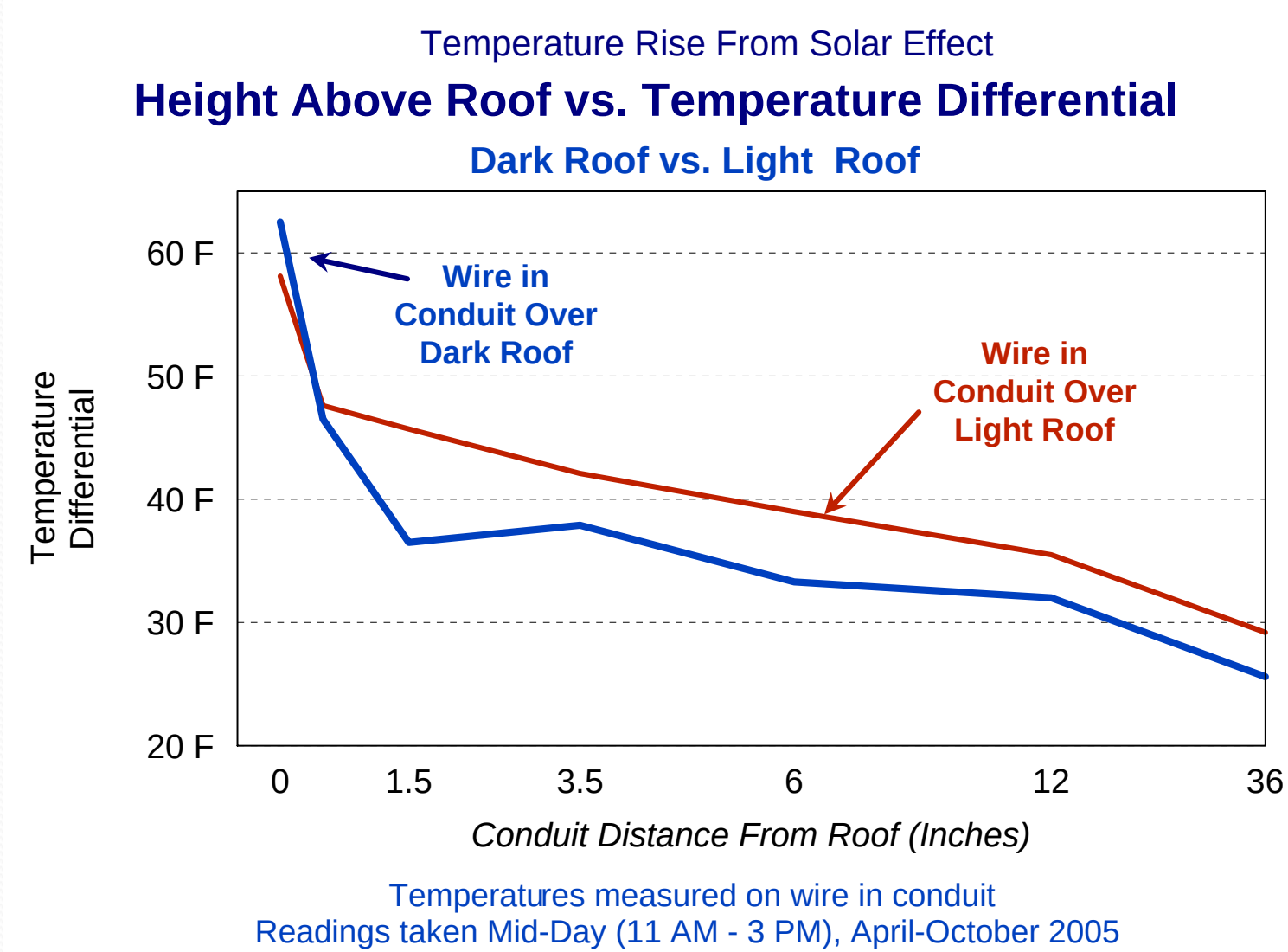
Temperature rise from solar radiation above black roof

Closer Conduit is to Roof Deck, the Higher the Differential

AVERAGE MID-DAY TEMPERATURE (Average of All Readings) UNLOADED

Black Roof (East)					**White** Roof (West)				
		Conduit/ Cable Bottom	Conduit/ Cable Top	On Insulation			Conduit/ Cable Bottom	Conduit/ Cable Top	On Insulation
EMT	On Deck	45.9	43.9	49.7	EMT	On Deck	42.5	42.9	42.4
EMT	5/8" above	33.4	33.1	34.4	EMT	5/8" above	33.9	33.9	33.7
EMT	1.5" above	26.2	25.2	25.6	EMT	1.5" above	30.9	32.5	32.5
EMT	3.5" above	24.5	24.4	24.8	EMT	3.5" above	28.8	29.1	28.0
EMT	6" above	22.7	22.6	21.6	EMT	6" above	27.4	27.8	27.0
EMT	12" above	19.8	20.3	20.2	EMT	12" above	24.1	24.6	23.7
EMT	36" above	17.4	18.1	17.3	EMT	36" above	20.5	21.2	19.9
RNC	On Deck	44.7	45.9	50.1	RNC	On Deck	42.6	52.7	49.0
RNC	5/8" above	39.0	36.3	39.8	RNC	5/8" above	35.2	48.3	42.0
RNC	1.5" above	28.7	38.0	30.1	RNC	1.5" above	33.5	36.7	39.3
RNC	3.5" above	28.8	36.0	33.0	RNC	3.5" above	32.3	41.5	36.5
RNC	6" above	28.2	33.1	28.5	RNC	6" above	30.8	39.6	34.0
RNC	12" above	25.1	32.1	27.0	RNC	12" above	28.3	30.4	31.0
RNC	36" above	19.5	22.7	21.3	RNC	36" above	21.6	31.3	25.7
MC	On Deck	53.1	49.5	59.8	MC	On Deck	51.1	48.5	51.5
MC	5/8" above	39.1	44.6	40.7	MC	5/8" above	36.5	39.4	39.5
MC	1.5" above	32.2	38.0	34.4	MC	1.5" above	35.2	39.1	35.7
MC	3.5" above	31.2	35.5	30.7	MC	3.5" above	28.8	38.4	31.7
MC	6" above	31.9	32.9	31.3	MC	6" above	29.6	36.5	30.6
MC	12" above	23.3	30.0	27.1	MC	12" above	26.7	28.8	28.0
MC	36" above	17.2	26.0	21.9	MC	36" above	26.1	21.0	22.0

Off Roof Deck, Differential is Greater Over Lighter Color Roof!



Off Roof Deck, Differential is Greater Over Lighter Color Roof!

AVERAGE MID-DAY TEMPERATURE (Average of All Readings) UNLOADED

		Black Roof (East)					**White** Roof (West)		
		Conduit/ Cable Bottom	Conduit/ Cable Top	On Insulation			Conduit/ Cable Bottom	Conduit/ Cable Top	On Insulation
EMT	On Deck	45.9	43.9	49.7	EMT	On Deck	42.5	42.9	42.4
EMT	5/8" above	33.4	33.1	34.4	EMT	5/8" above	33.9	33.9	33.7
EMT	1.5" above	26.2	25.2	25.6	EMT	1.5" above	30.9	32.5	32.5
EMT	3.5" above	24.5	24.4	24.8	EMT	3.5" above	28.8	29.1	28.0
EMT	6" above	22.7	22.6	21.6	EMT	6" above	27.4	27.8	27.0
EMT	12" above	19.8	20.3	20.2	EMT	12" above	24.1	24.6	23.7
EMT	36" above	17.4	18.1	17.3	EMT	36" above	20.5	21.2	19.9
RNC	On Deck	44.7	45.9	50.1	RNC	On Deck	42.6	52.7	49.0
RNC	5/8" above	39.0	36.3	39.8	RNC	5/8" above	35.2	48.3	42.0
RNC	1.5" above	28.7	38.0	30.1	RNC	1.5" above	33.5	36.7	39.3
RNC	3.5" above	28.8	36.0	33.0	RNC	3.5" above	32.3	41.5	36.5
RNC	6" above	28.2	33.1	28.5	RNC	6" above	30.8	39.6	34.0
RNC	12" above	25.1	32.1	27.0	RNC	12" above	28.3	30.4	31.0
RNC	36" above	19.5	22.7	21.3	RNC	36" above	21.6	31.3	25.7
MC	On Deck	53.1	49.5	59.8	MC	On Deck	51.1	48.5	51.5
MC	5/8" above	39.1	44.6	40.7	MC	5/8" above	36.5	39.4	39.5
MC	1.5" above	32.2	38.0	34.4	MC	1.5" above	35.2	39.1	35.7
MC	3.5" above	31.2	35.5	30.7	MC	3.5" above	28.8	38.4	31.7
MC	6" above	31.9	32.9	31.3	MC	6" above	29.6	36.5	30.6
MC	12" above	23.3	30.0	27.1	MC	12" above	26.7	28.8	28.0
MC	36" above	17.2	26.0	21.9	MC	36" above	26.1	21.0	22.0

Findings were certified and peer reviewed by IEEE

Product Safety and Quality
Electrical Services

James R. Dolphin
Email: jdolphin@us.tuv.com

November 20, 2009

Attn: Mr. Travis Lindsey
Travis Lindsey Consulting Services Inc.
2940 Redwood Street
Las Vegas, NV 89146
USA

File 30972302.001
ISO/IEC 17025 Audit
Letter of Recommendation

Dear Mr. Lindsey:

Please find enclosed with this letter our Laboratory Assessment Report which is based on the Second Edition of the International Standard for General Requirements for the Competence of Testing and Calibration Laboratories, ISO/IEC 17025:2005.

The undersigned engineer visited your Rooftop Temperature Testing Laboratory (RTTL) in Las Vegas on November 4 and 5, 2009, to complete work on the Laboratory Assessment Report and to assess in person the facilities and operation of the RTTL.

While we cannot comment on future work due to the absence of a Quality Manual and written test procedures, we did find that the RTTL has operated in accordance with the principles of ISO/IEC 17025:2005 and maintains records in accordance with the requirements of ISO/IEC 17025:2005.

Accordingly, TÜV Rheinland of North America, Inc. (TRNA), a Nationally Recognized Testing Laboratory (NRTL) under the Occupational Safety and Health Administration's NRTL Program, recognizes the validity of the data obtained by the RTTL up to and including the last day of the visit, November 5, 2009, and recommends the acceptance of that data by other parties that might be interested in using the data obtained.

Sincerely,
TÜV Rheinland of North America

Jim Dolphin
Senior Engineer

Reviewed by,
TÜV Rheinland of North America

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Division Manager

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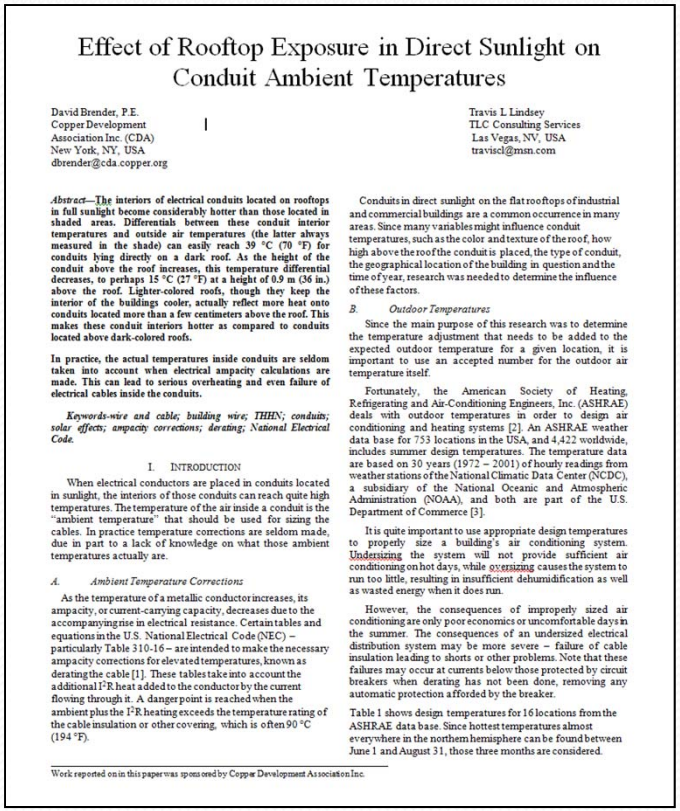

Effect of Rooftop Exposure in Direct Sunlight on Conduit Ambient Temperatures

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***Abstract*—The interiors of electrical conduits located on rooftops in full sunlight become considerably hotter than those located in shaded areas. Differentials between these conduit interior temperatures and outside air temperatures (the latter always measured in the shade) can easily reach 39 °C (70 °F) for conduits lying directly on a dark roof. As the height of the conduit above the roof increases, this temperature differential decreases, to perhaps 15 °C (27 °F) at a height of 0.9 m (36 in.) above the roof. Lighter-colored roofs, though they keep the interior of the buildings cooler, actually reflect more heat onto conduits located more than a few centimeters above the roof. This makes these conduit interiors hotter as compared to conduits located above dark-colored roofs.**

In practice, the actual temperatures inside conduits are seldom taken into account when electrical ampacity calculations are made. This can lead to serious overheating and even failure of electrical cables inside the conduits.

Keywords-wire and cable; building wire; THHN; conduits; solar effects; ampacity corrections; derating; National Electrical Code.

I. INTRODUCTION

When electrical conductors are placed in conduits located in sunlight, the interiors of those conduits can reach quite high temperatures. The temperature of the air inside a conduit is the "ambient temperature" that should be used for sizing the cables. In practice temperature corrections are seldom made, due in part to a lack of knowledge on what those ambient temperatures actually are.

A. Ambient Temperature Corrections

As the temperature of a metallic conductor increases, its ampacity, or current-carrying capacity, decreases due to the accompanying rise in electrical resistance. Certain tables and equations in the U.S. National Electrical Code (NEC) – particularly Table 310-16 – are intended to make the necessary ampacity corrections for elevated temperatures, known as derating the cable [1]. These tables take into account the additional I^2R heat added to the conductor by the current flowing through it. A danger point is reached when the ambient plus the I^2R heating exceeds the temperature rating of the cable insulation or other covering, which is often 90 °C (194 °F).

Conduits in direct sunlight on the flat rooftops of industrial and commercial buildings are a common occurrence in many areas. Since many variables might influence conduit temperatures, such as the color and texture of the roof, how high above the roof the conduit is placed, the type of conduit, the geographical location of the building in question and the time of year, research was needed to determine the influence of these factors.

B. Outdoor Temperatures

Since the main purpose of this research was to determine the temperature adjustment that needs to be added to the expected outdoor temperature for a given location, it is important to use an accepted number for the outdoor air temperature itself.

Fortunately, the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) deals with outdoor temperatures in order to design air conditioning and heating systems [2]. An ASHRAE weather data base for 753 locations in the USA, and 4,422 worldwide, includes summer design temperatures. The temperature data are based on 30 years (1972 – 2001) of hourly readings from weather stations of the National Climatic Data Center (NCDC), a subsidiary of the National Oceanic and Atmospheric Administration (NOAA), and both are part of the U.S. Department of Commerce [3].

It is quite important to use appropriate design temperatures to properly size a building's air conditioning system. Undersizing the system will not provide sufficient air conditioning on hot days, while oversizing causes the system to run too little, resulting in insufficient dehumidification as well as wasted energy when it does run.

However, the consequences of improperly sized air conditioning are only poor economics or uncomfortable days in the summer. The consequences of an undersized electrical distribution system may be more severe – failure of cable insulation leading to shorts or other problems. Note that these failures may occur at currents below those protected by circuit breakers when derating has not been done, removing any automatic protection afforded by the breaker.

Table 1 shows design temperatures for 16 locations from the ASHRAE data base. Since hottest temperatures almost everywhere in the northern hemisphere can be found between June 1 and August 31, those three months are considered.

Work reported on in this paper was sponsored by Copper Development Association Inc.

Effect of Rooftop Exposure On Conduit Ambient Temperatures

- Ambient Temperature Correction
- CDA Research Program
- Solar Radiation
- Expanded research
- Research Findings
- Conclusions

Recommended Ambient Temperature Adjustments

Based on conservative readings…

…e.g. Recommend using 2% ASHRAE design temperature criterion…

City	2% Design Temp. °C	1% Design Temp. °C	Max Temp. °C *
Phoenix, AZ	43	44	49
Las Vegas, NV	44	43	48
Wichita, KS	38	39	45
Houston, TX	36	36	42
Atlanta, GA	34	35	41
New Orleans, LA	34	35	39
Denver, CO	34	35	41
Miami, FL	33	33	38
New York, NY	33	34	40
Chicago, IL	33	34	40
Minneapolis/St. Paul, MN	32	33	41
Boston, MA	32	33	40
Pittsburgh, PA	31	32	39
Los Angeles, CA	26	27	42
San Francisco, CA	25	28	40
Fairbanks, AK	24	28	36

...and using 10% ambient temperature adjustments

Temperature Rises Inside EMT Conduits in Full Sunlight at Various Heights Above Roof, Based on Percentile of Reading							
	Temperature Rise Above Outdoor Temperature, °C*						
Percentile**	**On Roof**	**½ in above**	**1 ½ above**	**3 ½ above**	**6 in above**	**12 in above**	**36in above**
0% (max.)	40	27	26	24	23	21	17
1%	39	27	25	23	22	20	16
2%	38	26	25	23	22	20	16
5%	37	26	25	22	21	19	15
10%	**37**	**26**	**24**	**22**	**20**	**18**	**15**
50% (median)	34	24	22	20	18	16	14

* Average values for light and dark roofs..

** Measured from top.

Table 6. Recommended Adjustments (Additions) to Outdoor Temperatures to Determine Ambient Temperatures Inside Conduits

Table 310.15(B)(2)(c)

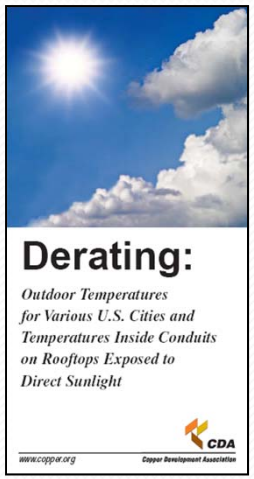
Distance Above Roof	Temperature	
	°C	°F
On roof, up to and including ½ in. above roof	33	60
Above ½ inch, up to and including 3 ½ in. above roof	22	40
Above 3-½ inches, up to and including 12 in. above roof	17	30
Above 12 inches, up to and including 36 in. above roof	14	25

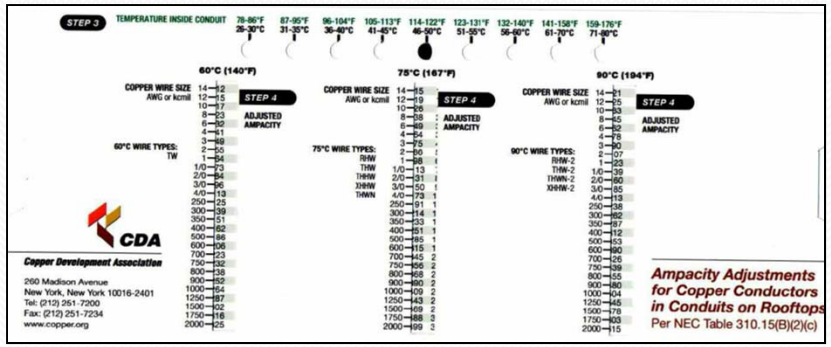
Mandatory in 2008 & 2011 NEC

Conversions

Deg C	Deg F		Deg C	Deg F
14	57.2		32	89.6
15	59		33	91.4
16	60.8		34	93.2
17	62.6		35	95
18	64.4		36	96.8
19	66.2		37	98.6
20	68		39	102.2
21	69.8		39	102.2
22	71.6		40	104
23	73.4		41	105.8
24	75.2		42	107.6
25	77		43	109.4
26	78.8		44	111.2
27	80.6		45	113
28	82.4		46	114.8
29	84.2		47	116.6
30	86		48	118.4
31	87.8		49	120.2

Free Tools to Perform Adjustment





Web site with temperature data:

http://www.copper.org/buildingwire

Or call: 888-480-WIRE

Questions?

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or

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