POEP LIMIT PROPOSAL

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SYSTIMAX SOLUTIONS

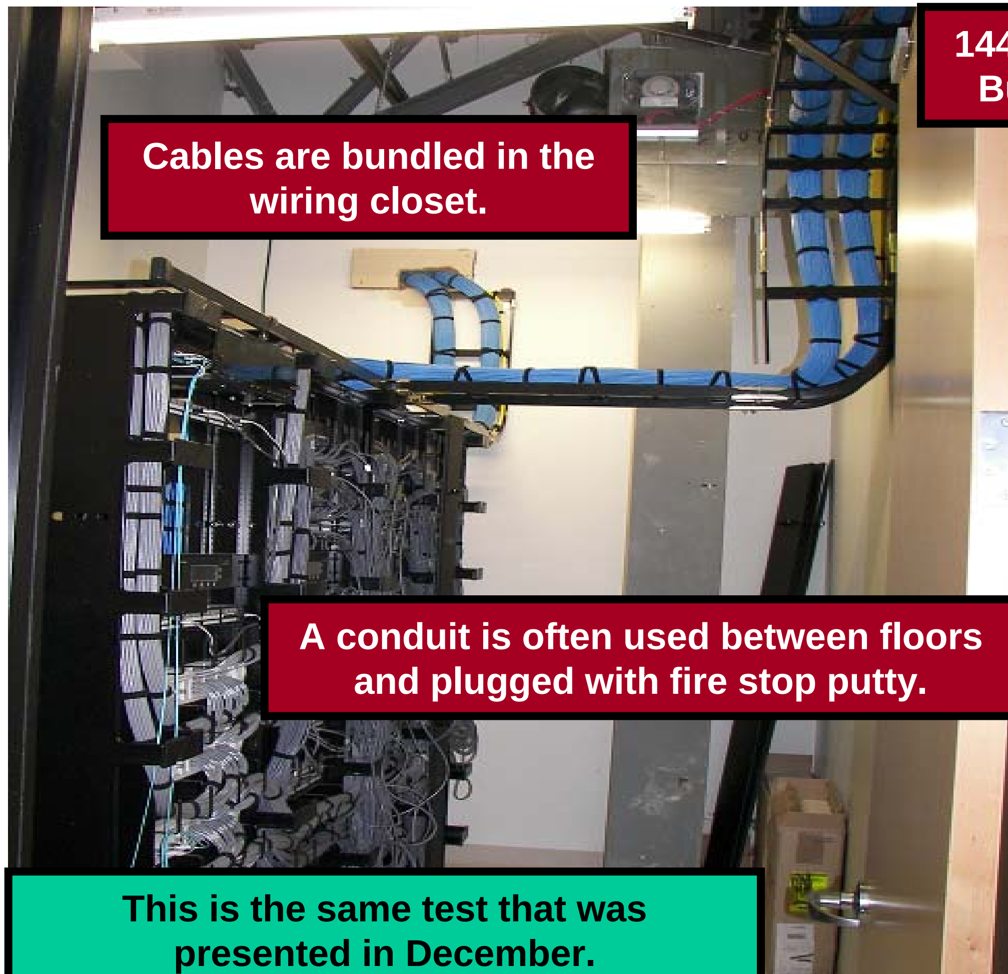
Proposal

- This is a proposal on POEP limits for the draft.
  - It is based on an independent study of temperature rise.
  - and agrees with the recommendations from TIA.
- The limits should not require changes in most of the installations that use POEP.
- There are four variables that control the temperature rise, a limit is required for all:
  - Current,
  - cable bundle size,
  - ambient temperature,
  - and cabling installation.
- A maximum current of 0.72 amps per pair is used in this presentation.
- The analysis sometimes chooses numbers to simplify the calculations to reach a limit.
- It is impossible to test all cabling configurations and these results only represent one set of tests.

Requirements

- **TIA has recommended only a 10°C rise in the cable temperature and de-rating for ambient temperatures above 45 °C.**
- **IEEE requirement, IEC 60950-1 sub-clause 6.3 Protection of the telecommunication wiring system from overheating.**
  - **These requirements are on the equipment that supplies the current to the cable.**
- **For general wiring, *NEC* Article 310.10: "In no case shall conductors be associated together in such a way, with respect to type of circuit, the wiring method employed, or the number of conductors, that the limiting temperature of any conductor is exceeded."**

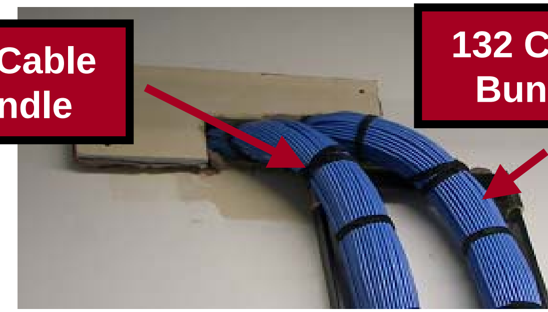
TEST



Cables are bundled in the wiring closet.

144 Cable Bundle

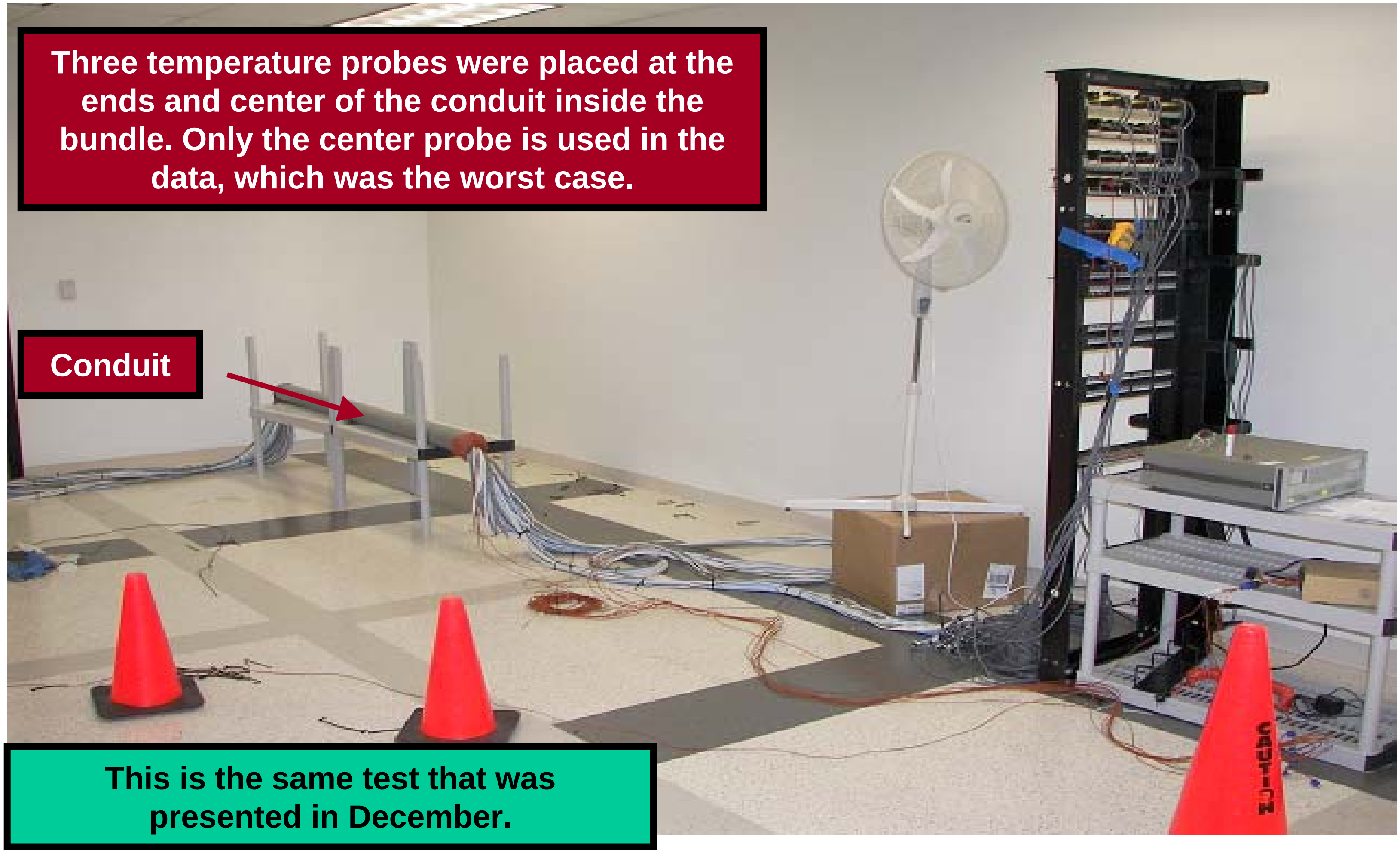
132 Cable Bundle



A conduit is often used between floors and plugged with fire stop putty.

This is the same test that was presented in December.

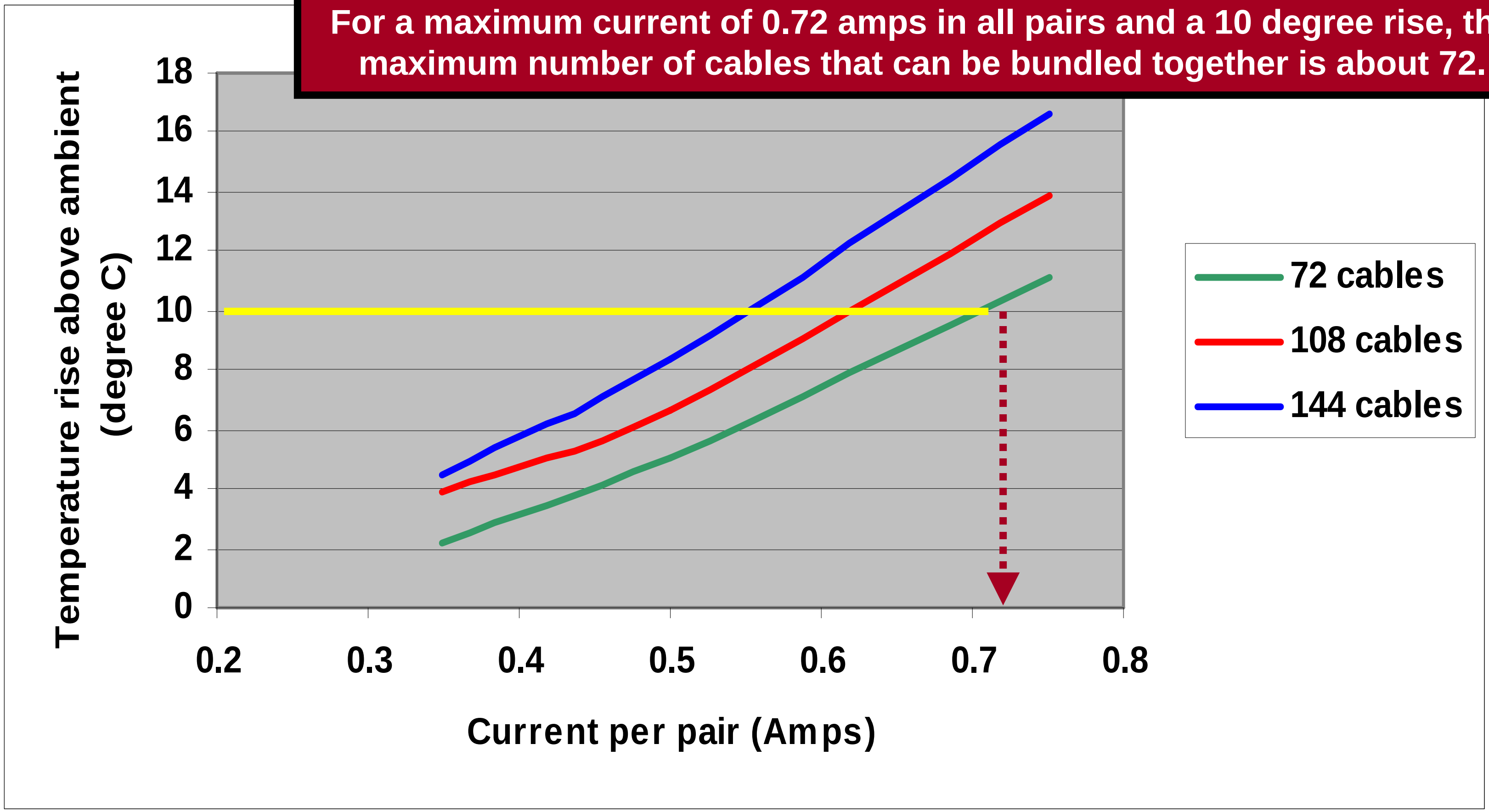
Test Set Up



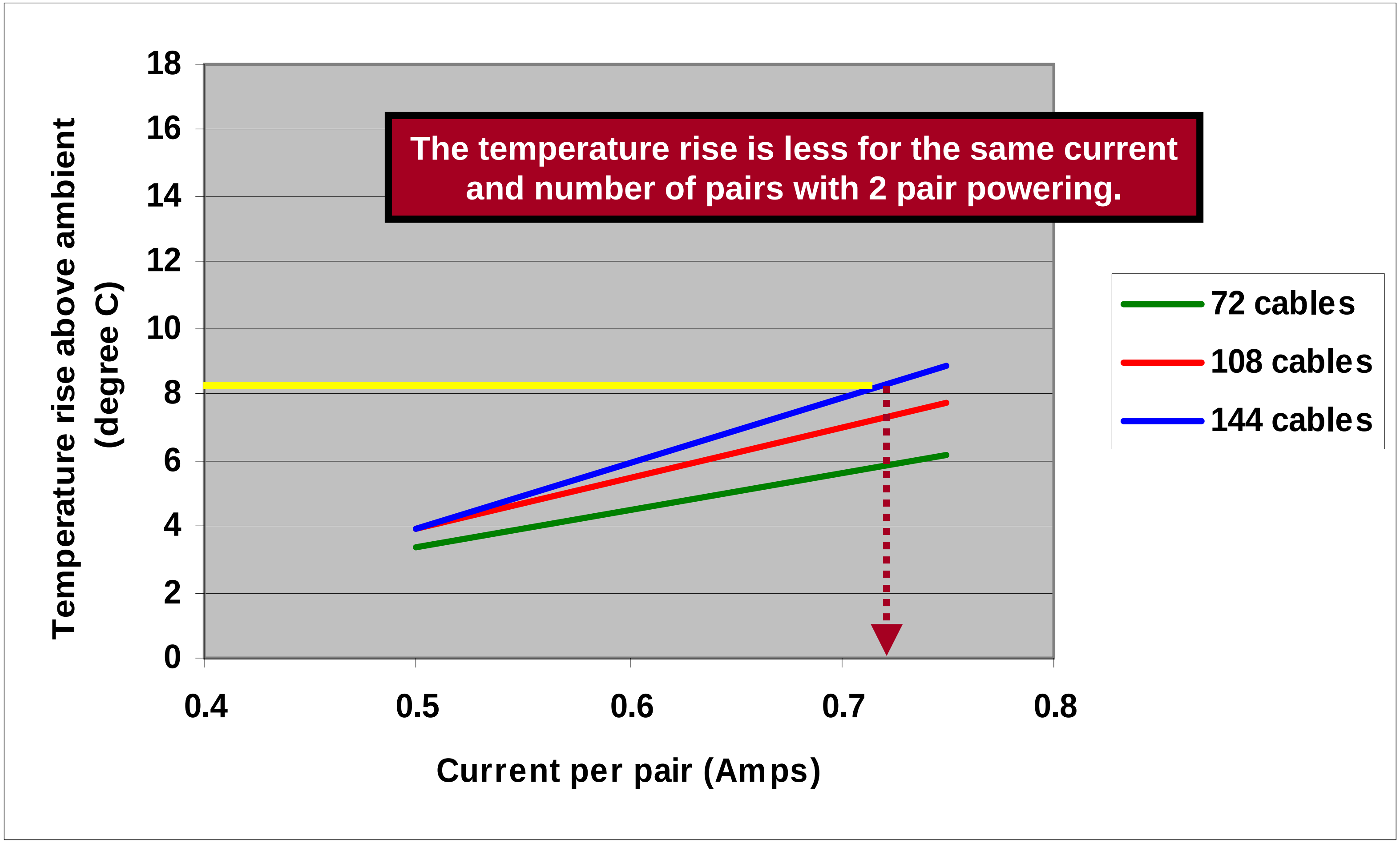
Three temperature probes were placed at the ends and center of the conduit inside the bundle. Only the center probe is used in the data, which was the worst case.
Conduit
This is the same test that was presented in December.
CAUTION

Cat 5e 4 pair power

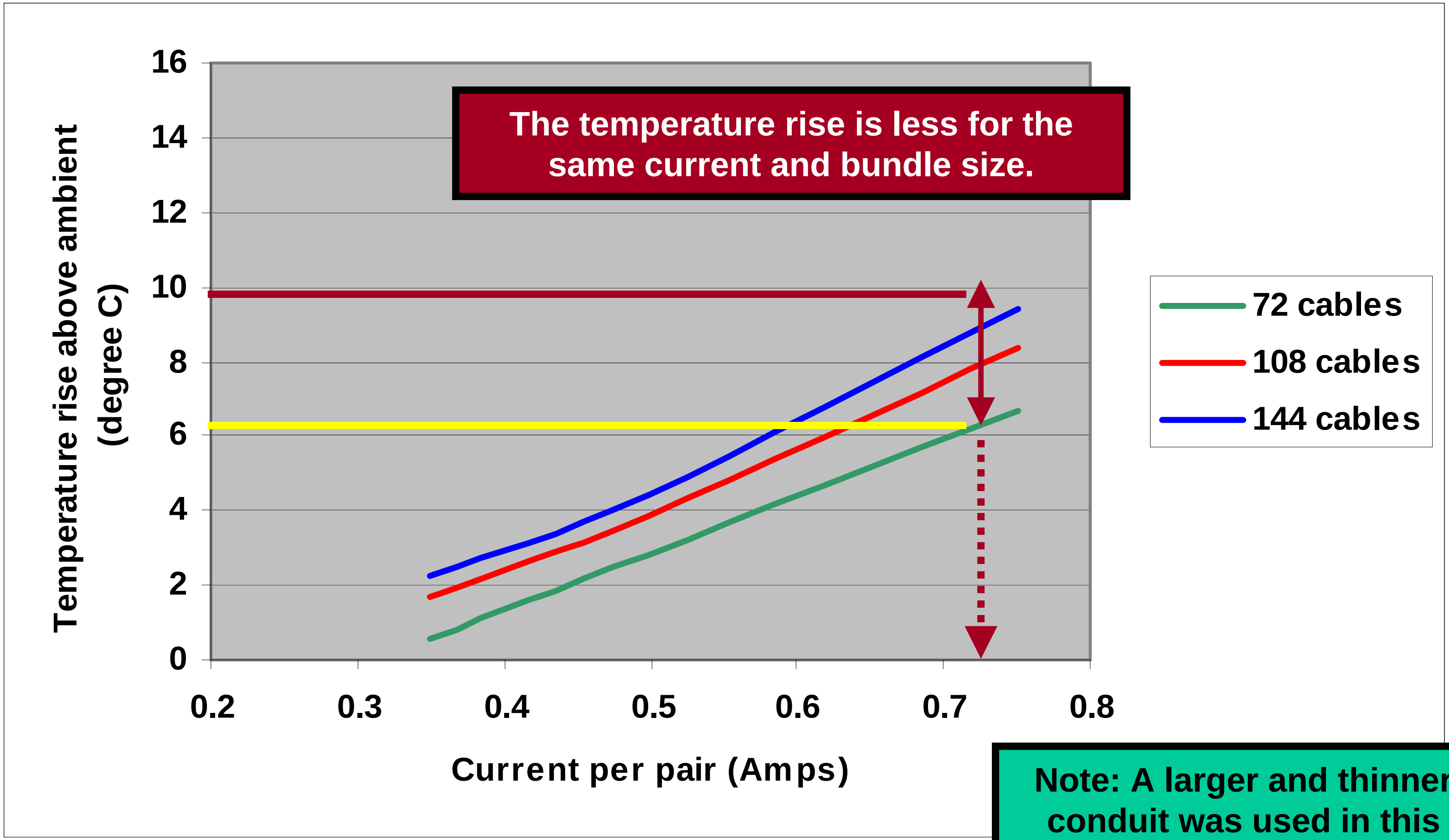
For a maximum current of 0.72 amps in all pairs and a 10 degree rise, the maximum number of cables that can be bundled together is about 72.



Also for Cat 5e 2 pair power

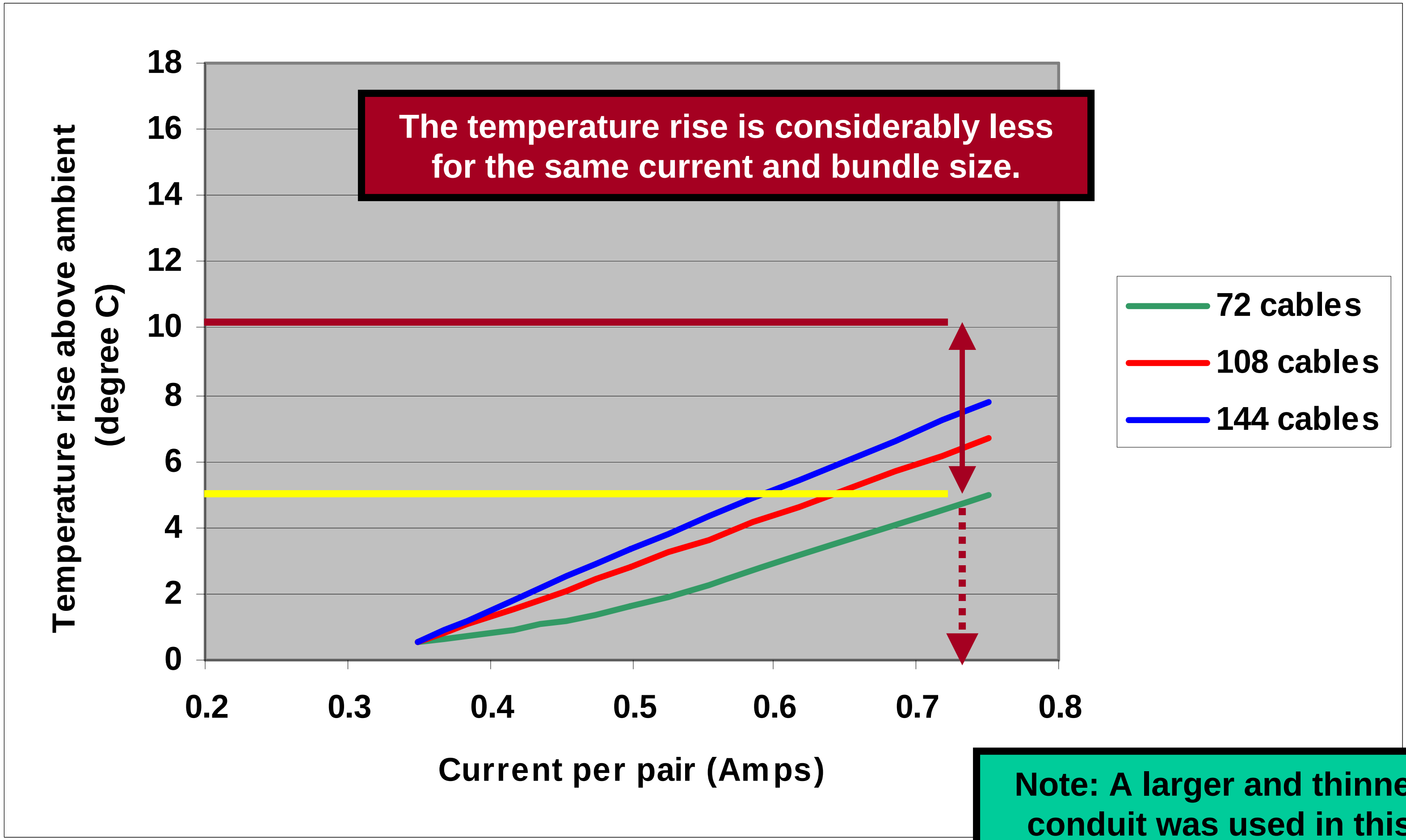


Cat 6 4 pair power



Note: A larger and thinner conduit was used in this test then with Cat 5e.

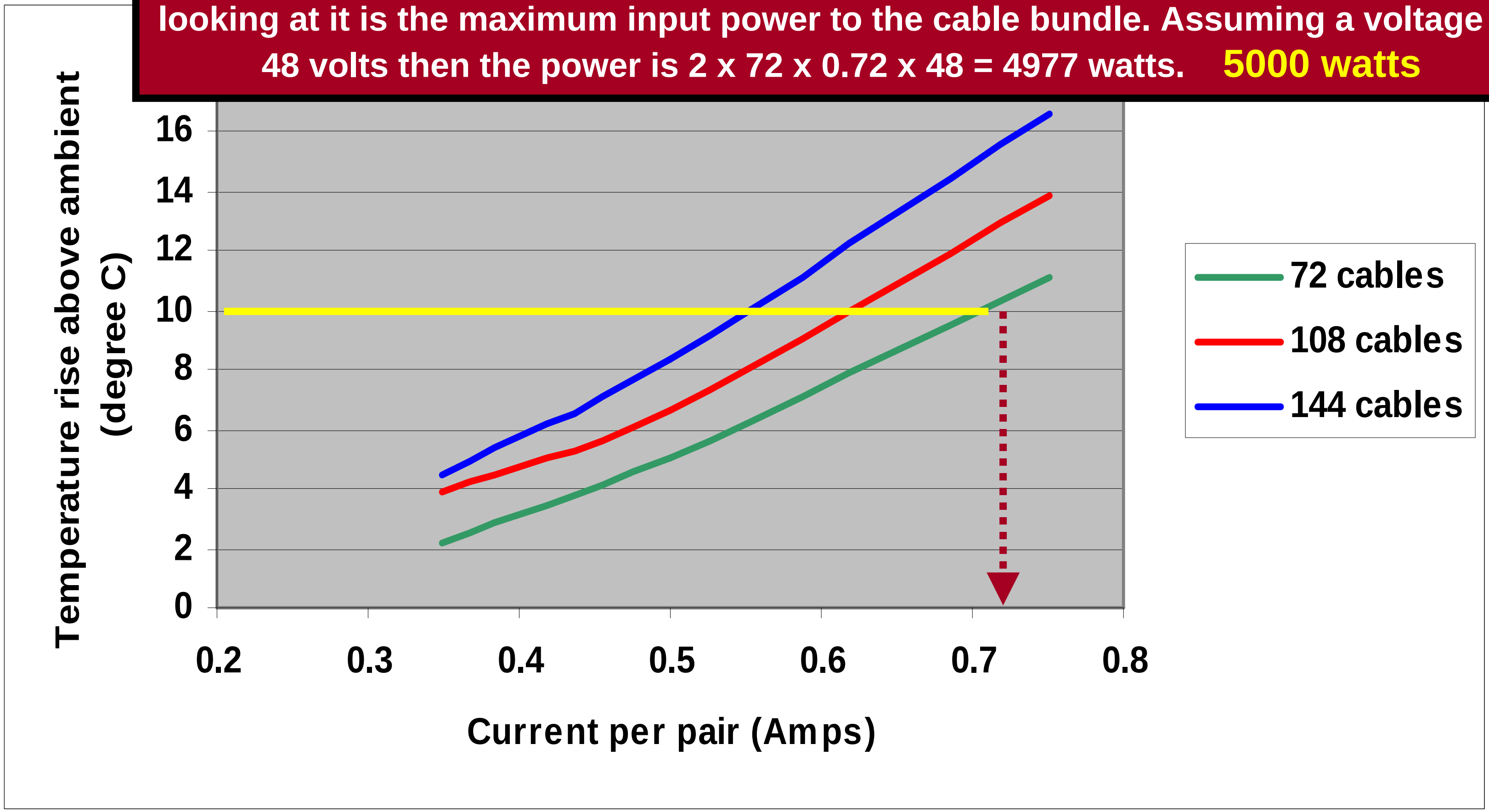
Cat 6A 4 pair power



Note: A larger and thinner conduit was used in this test then with Cat 5e.

Maximum Power

Using a limit on the number of cables would be too restrictive. Another way of looking at it is the maximum input power to the cable bundle. Assuming a voltage of 48 volts then the power is 2 x 72 x 0.72 x 48 = 4977 watts. 5000 watts



Maximum Bundle Size

- The choice of 48 volts for the input is somewhat arbitrary but the 5000 watts is probably a good round number to use.
- But if we choose the minimum voltage in the calculation then we can prove that any other cable bundle whose input power does not exceed this maximum power, 2 x 72 x 0.72 x Vmin, will dissipate less power and generally less heat, see back up proof.
- This allows for the power or current into any pair of a cable bundle to be different and does not distinguish between two or four pair powering, it's only the sum that's important.
- It is easy to determine up front if the installation needs to be looked at and the 5000 watts is so large that it will not have an impact on most installation.

Proposed Baseline Text # 1

Installations which use any cabling defined in ISO/IEC 11801 Ed2.1, TIA-568-B.1, or TIA-568-B.2-10 and follow the installation guidelines for those cables will safely support the installation of all powered devices defined in Clause 33. This sub-clause defines the maximum limits and is not expected to impact most installations.

When power is applied to a cable the temperature of the cable will rise due to the current flow resistance of the cable. To limit the temperature rise on an individual cable the maximum continuous current per cable pair shall be limited to 0.72 amps.

When cables are bundled together this will increase the temperature of each cable. To limit the temperature rise of a cable in a bundle the maximum power that can be applied to a cable bundle shall be 5000 watts from all PSE's connected to that cable bundle.

Conductor Rating

ARTICLE 310: Conductors for General Wiring

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						
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	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	
or kcmil	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			or kcmil
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

Conductor De-rating

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	[illegible]	[illegible]	[illegible]	78-86
31-35	0.91	0.94	0.96	[illegible]	[illegible]	[illegible]	87-95
36-40	0.82	0.88	0.91	[illegible]	[illegible]	[illegible]	96-104
41-45	0.71	0.82	0.87	[illegible]	[illegible]	[illegible]	105-113
46-50	0.58	0.75	0.82	[illegible]	[illegible]	[illegible]	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

* **Small Condutors.** Unless specifically permitted in 240.4(E) through (G), the overcurrent protection shall not exceed 15 amperes for 14 AWG, 20 amperes for 12 AWG, and 30 amperes for 10 AWG copper; or 15 amperes for 12 AWG and 25 amperes for 10 AWG aluminum and copper-clad aluminum after any correction factors for ambient temperature and number of conductors have been applied.

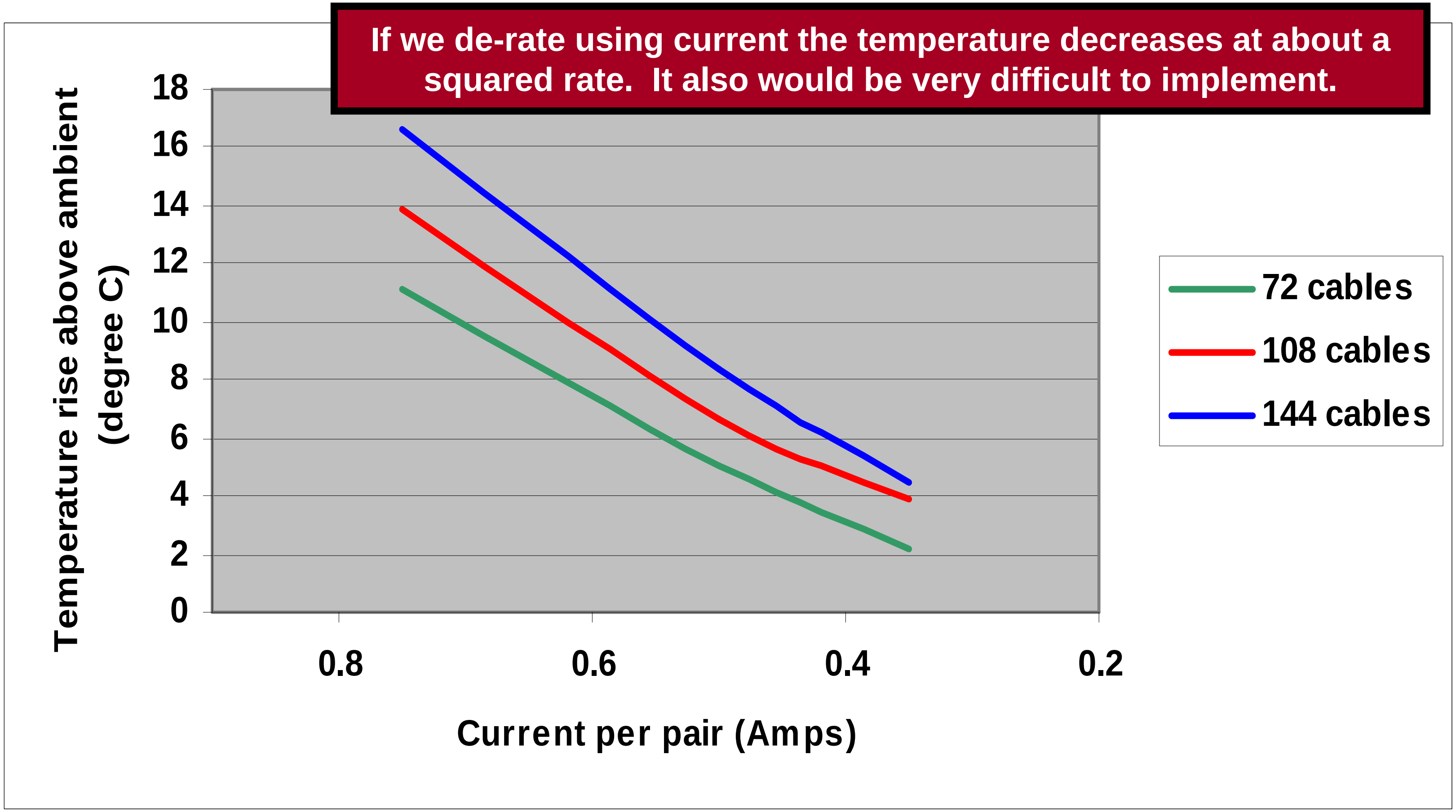
***NEC* de-rates the current rating of the cable based on ambient temperature.**

***NEC* does not allow power to a 60°C rated cable when the ambient temperature is 56°C or greater. Note: *NEC* defines the ambient temperature when power is being applied.**

Limiting the Temperature Rise

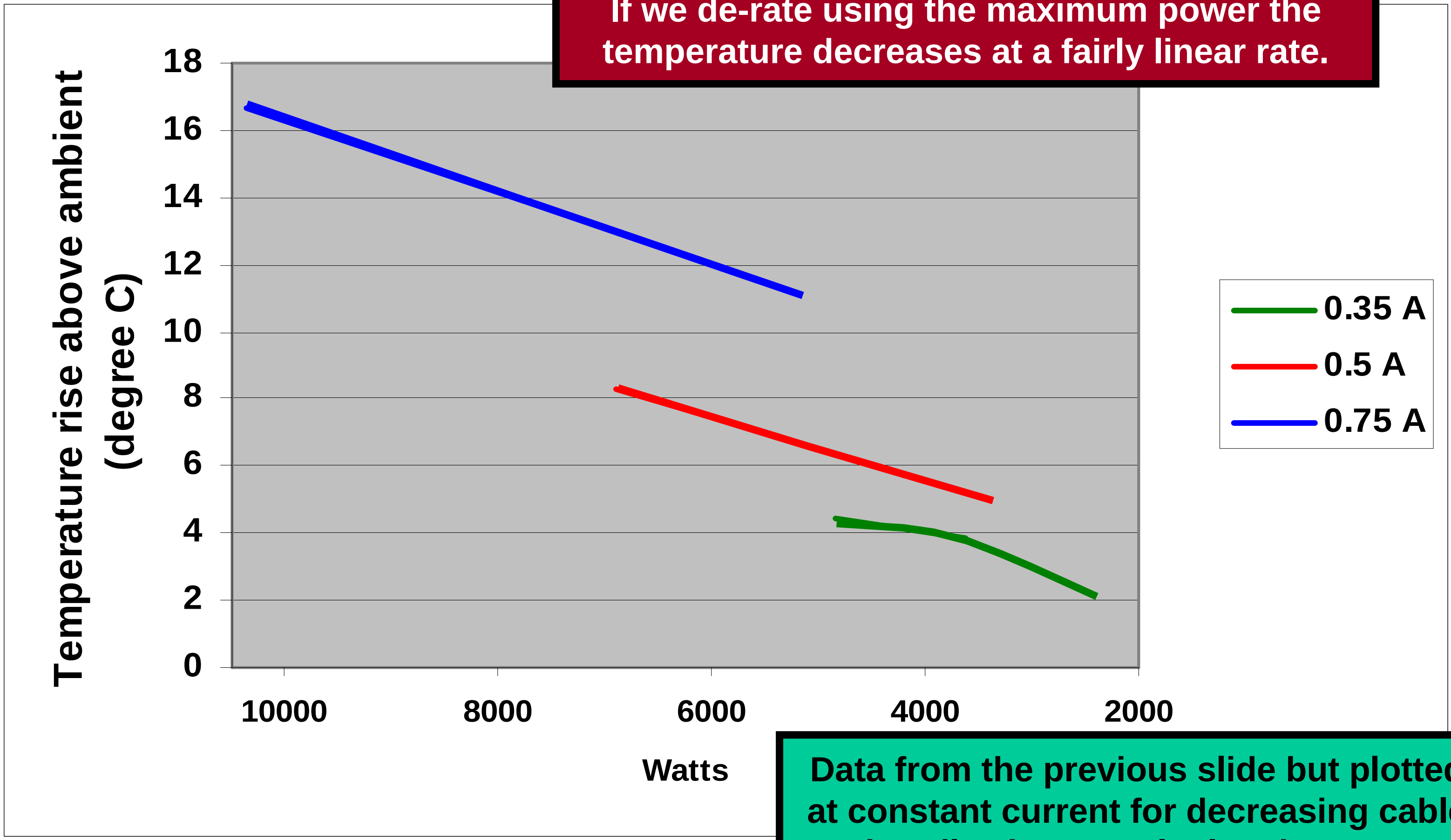
- **As the ambient temperature approaches the maximum then the temperature rise must be reduced. The best method would be to de-rate the input as in the *NEC* requirements.**
- **The only other alternative is not to put current on the cable above a certain ambient temperature.**

Current De-rating



Power De-rating

If we de-rate using the maximum power the temperature decreases at a fairly linear rate.



Data from the previous slide but plotted at constant current for decreasing cable bundles but as calculated power.

De-rating

- By de-rating the maximum power we can limit the temperature rise to stay below the maximum temperature.
- It is very easy to implement by knowing the maximum power of the PSE's or knowing the maximum power requirements of the PD's, that are connected to the cable bundle.
- It also allows for any current up to the maximum current on any or all cable pairs.
- TIA has recommended de-rating for temperatures above 45°C.
  - The maximum power is large enough but the temperature may be more of a limiting factor. We may want to allow a higher temperature de-rating for some cables.
- If you allow the current to be a maximum for all power levels then you must de-rate to a temperature that is less then 60°C to account for that last bit of temperature rise.

De-rating Factor

- If we start the de-rating at 46°C then we must determine another point on the line, preferably one close to the end of the de-rating but not too small.
- We can use a 37 cable bundle and the data in:
  - jul06/delveaux_1_0706 for Category 5e
  - sep06/delveaux_2_0906 for Category 6A.
- The current used for the test was 0.84 amps but since the test was not conducted in a conduit the temperature rise would have been worse and it does not account for the increase in resistance at higher temperatures.

De-rating Factor

- To pick possible de-rating factors we will first determine the de-rating for 30 watts 2 pair powering. We will then go back and calculate the temperature rise for all cases using a rounded de-rating factor.
- We will assume 35 watts into each pair for simplicity. From the data the worst temperature rise for Category 5e is 4.22°C and 3.01°C for Category 6A.
- We will use a maximum temperature rise of 56°C for the calculation.
  - A temperature rise of 10°C plus a 10% increase due to the increased resistance at higher temperatures from an ambient of 45°C.
  - The temperature rise should decrease somewhat linearly and stay around 56°C as the ambient goes up.

De-rating Factor

The equation for de-rating is,

$$5000 \text{ (watts)} - X [T_{ambient} - 45°C] = 37 \text{ (cables)} \times 35 \text{ (watts)}$$

Where X is the de-rating factor.

Solving for X,

$$X = (5000 - 37 \times 35) / (T_{ambient} - 45).$$

If we assume a maximum temperature of 56°C then,

$$X = (5000 - 37 \times 35) / [(56 – T_{rise}) - 45]$$

Where Trise is the temperature rise.

De-rating Factor

Then,

For Category 5e X = 546 watts/°C, or rounded to 500 watts/°C.

In the case of Category 6A we will begin the de-rating at a higher temperature of 50°C.

And for Category 6A X = 929 watts/°C, or rounded to 900 watts/°C.

Temperature Rise

- With these de-ratings:
  - For Category 5e.
    - At 50°C the power is still 2500 watts and the de-rating ends at 500 watts at 54°C.
  - For Category 6A.
    - At 50°C the power is still 4100 watts and the de-rating ends at 500 watts at 54°C.

Temperature Rise

- We now calculate a temperature rise for two and four pair powering.
  - We will use the same data and the ambient is the temperature at which the de-rated power is equal to 37 cables times 35 watts or 70 watts for four pair powering.
- I also will include Category 6 by assuming it's temperature rise is half way between Category 5e and 6A.

Temperature Rise

.
The calculated temperature for a 37 cable bundle with an ambient temperature based on the maximum de-rated power to the bundle:

Cat 5e 2 pair	Cat 5e 4 pair	Cat 6 2 pair	Cat 6 4 pair	Cat 6A 2 pair	Cat 6A 4 pair
Temp rise 4.22°C	Temp rise 7.68°C	Temp rise 3.6°C	Temp rise 6.4°C	Temp rise 3.01°C	Temp rise 5.06°C
56.6°C	57.5°C	56.0°C	56.2°C	56.1°C	56.7°C

All the temperatures are 56.1°C to 56.7°C with the exception of Category 5e four pair powering.

Proposed Baseline Text # 2

The environment of the cable bundle will affect the magnitude of the temperature rise. When the ambient temperature around the cable bundle exceeds 45°C the maximum power to the cable bundle must be reduced. The maximum power to a cable bundle shall be decreased by 500 watts per °C for ambient temperatures of 46°C or greater. For installations that use Class E_A or Class F cabling the maximum power to a cable bundle shall be decreased by 900 watts per °C for ambient temperatures of 50°C or greater. The ambient temperature is defined as the temperature of the air surrounding the cable bundle when power is not being supplied to the cables.

It would be worthwhile to include an informative annex providing examples on how to implement this. In addition add this requirement:

It is required that the PSE or PD (and supporting documentation) be labeled in a manner visible to the user with the maximum aggregate power that can be supplied to all PI ports in a PSE and the maximum power that may be required by the PD.

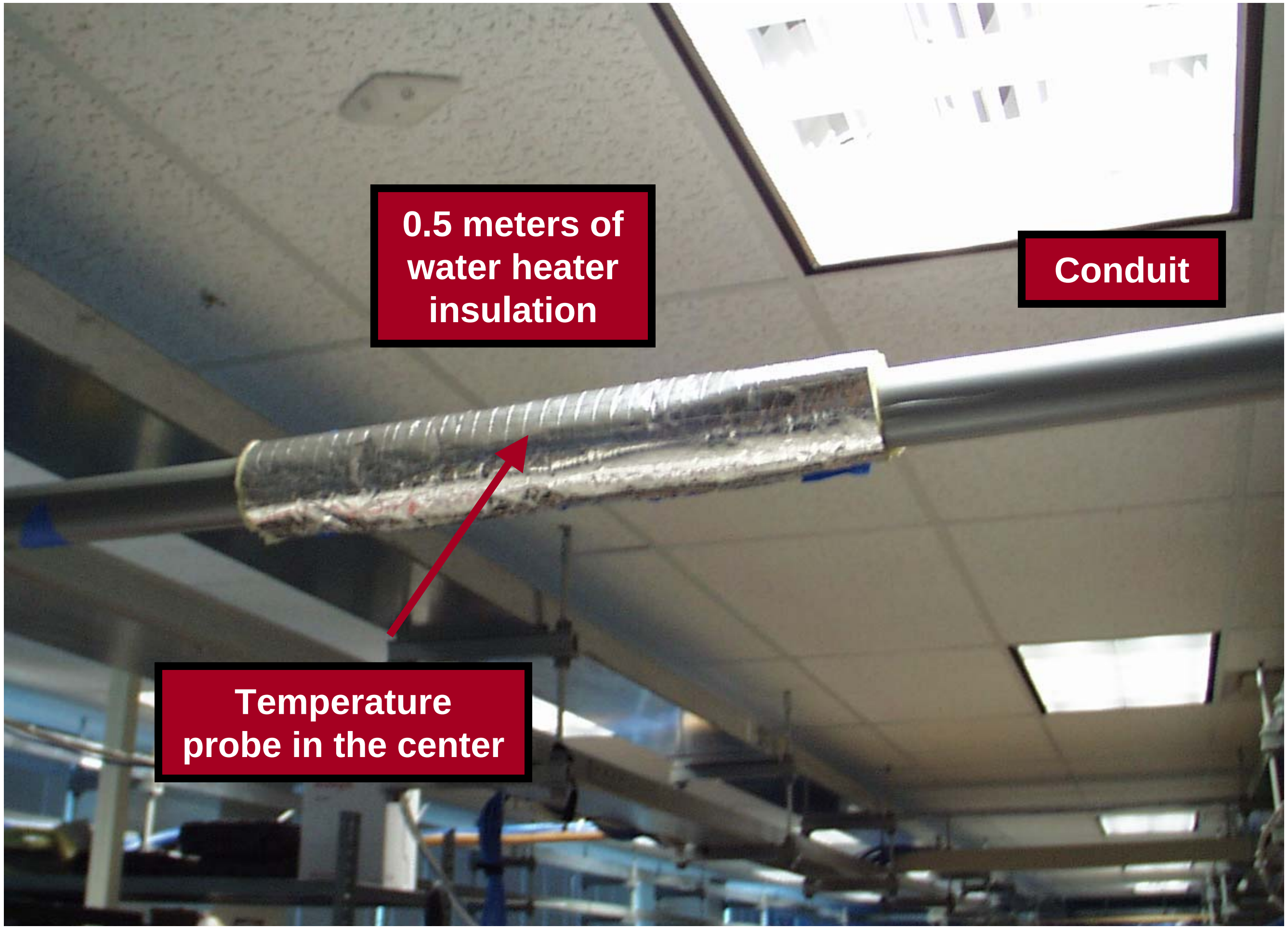
Proposed Baseline Text # 3

These requirements are intended that the cabling installation will operate within it's rated temperature. The temperature rise of the cable is related to the resistance per length of the individual wires on a cable. A higher class or category of solid copper cable, such as Class E (Category 6), will generally have a lower resistance per length and Class E_A (Category 6_A) or Class F, does have a lower resistance per length. For installations that power all four pairs of a cable it is recommended that a Class E or better cabling should be used.

Insulated Conduit

- A presentation in may06/dupuis_1_0506 illustrated that it was possible to significantly increase the temperature in a conduit by wrapping the conduit with insulation.
- We should recommend that the conduit or even cabling not be insulated.
- But we must allow for the conduit to go thru walls. The following test tries to simulate this.

Insulated Conduit Test



Insulated Conduit Results

- The temperature rise was 60% more then when there was no insulation.
- At an ambient of 45°C and a 10°C rise this would put the cable temperature at about 61°C, and this does not include the increase in temperature due to increased resistance.
- But the temperature rise will only be over the 0.5 meters of the cable with the insulation.
- It is an example of why we begin de-rating at 45°C instead of 50°C and end before 60°C, to allow some margin.

Proposed Baseline Text # 4

To ensure sufficient air flow, cable bundles and cable trays or conduits should not be insulated, surrounded, or encased with additional material for more than 0.5 meters along the length of the cable bundle, tray, or conduit.

This is something that TIA should take a closer look at.

Back Up Proof

The heat generated by a cable is related to the power that is dissipated on the cable. We want to specify a maximum power so that the power dissipated on any other cable bundle, that is limited to this maximum power, is less. The maximum power is *Pmax = M x Imax x Vmin*, where *Imax* is the maximum current and *Vmin* is the minimum voltage from the PSE. *M* is the maximum number of cables that can be bundled together for a specified temperature rise. We will omit the 2 for simplicity.

Then for any bundle size of *N,* the total power is the sum of the input power from each cable, defined as *Pi*, and is specified to be less than or equal to *Pmax*.

$$\sum_{i=1}^{i=N} Pi \le P\max \qquad \text{or} \qquad \sum_{i=1}^{i=N} Pi \le M \times \mathrm{Im}\,ax \times V\min$$

Dividing by *1/Vmin* $\frac{1}{V\min} \times \sum_{i=1}^{i=N} Pi \le M \times \mathrm{Im}\,ax$

Since the voltage on any pair of the other bundle, *Vi,* is equal to or larger then *Vmin*

and $\frac{1}{Vi} \le \frac{1}{V\min}$ we can substitute *Vi* for *Vmin* on the left and move this inside the sum and not change the inequality $\sum_{i=1}^{i=N} \frac{Pi}{Vi} \le M \times \mathrm{Im}\,ax$

Pi divided by *Vi* is just the current in the *i* th pair, the equation becomes $\sum_{i=1}^{i=N} Ii \le M \times \mathrm{Im}\,ax$

Multiplying both sides by *Imax x R. R* is the loop resistance.

$$\mathrm{Im}\,ax \times R \times \sum_{i=1}^{i=N} Ii \le M \times \mathrm{Im}\,ax^2 \times R$$

Since the current in any pair of the other bundle is always less than or equal to *Imax* we can substitute *Ii* for *Imax* on the left side and move it inside the sum and not change the inequality.

$$\sum_{i=1}^{i=N} Ii^{2} \times R \le M \times \mathrm{Im}\,ax^2 \times R$$

Since the terms on the right are constants we can write this as a sum and eliminate *M.*

$$\sum_{i=1}^{i=N} Ii^2 \times R \le \sum_{1}^{M} \mathrm{Im}\,ax^2 \times R$$

Which says the power disipated on any cable bundle is always less than or equal to the power dissipated on the bundle that we use to calculate the maximum power.