MUSIC CITY POWER QUALITY
IEEE Central Tennessee Section

Harmonic Mitigating, Energy Efficient, and Other Dry Type Distribution Transformer Technologies

- Click to edit Master subtitle style

David Simmons, P.E.
LEED Accredited Professional
Product Manager – Value-Add Transformers

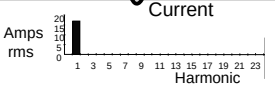
Transformer Evolution

- **Standard Delta-Wye** – since 1880
- **K-Rated** Circa 1980's – in response to harmonics; over-sized
- **HMT** – re-design of transformer to let the loads operate as designed (producing harmonics); but minimize the impact of the harmonics on our electrical systems
- **CSL-3** – Energy Efficiency / Green

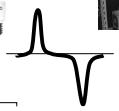
The Equipment in our Buildings has Changed

Linear Loads
(Loads of the past):

Current



Non-Linear Loads
(Loads of today):



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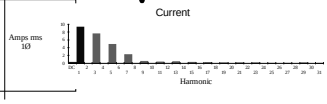


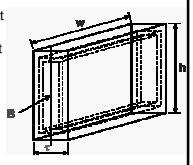
Transformer Losses
Frequency can be a killer

Eddy-current losses

The AC flux induces emfs in the core that produce eddy currents that circulate in the iron. Eddy-current losses are proportional to the frequency, the maximum flux density, the thickness of the core sheet and the resistivity of the iron (inversely).

$$P_e = \frac{Vol \cdot \pi^2 \cdot f^2 \cdot \tau^2 \cdot B^2}{6\rho}$$

$$Vol = w \cdot t \cdot h$$

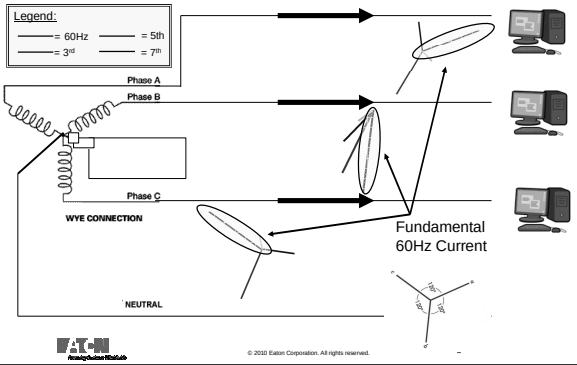


"At 100% THD, the copper loss doubled, and the eddy current loss increased by more than 17 times. Consequently, the 112-kVA transformer is overloaded by only 60 kW of computers."

IEEE Transactions on Industry Applications, Sept/Oct. '96
"Costs and Benefits of Harmonic Current Reduction for Switch-Mode Power Supplies in a Commercial Office Building"

Tom Key, PEAC
Jih-Sheng Lai, Oak Ridge National Lab, Lockheed Martin Energy Research

How harmonic currents move in a typical electrical system



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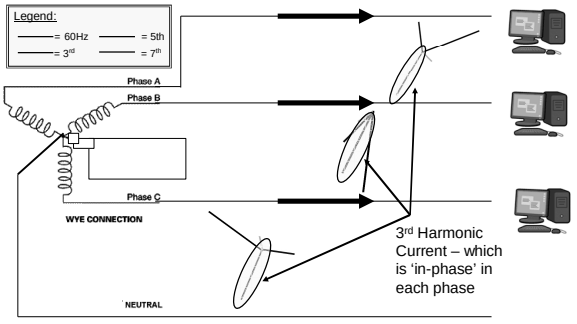

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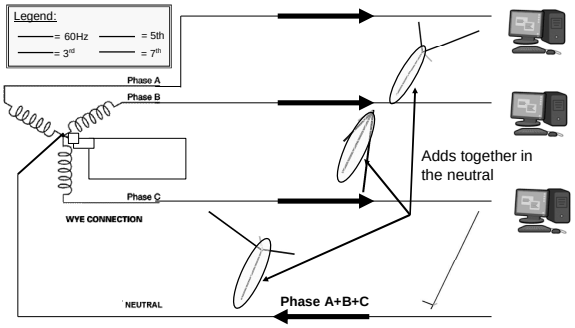
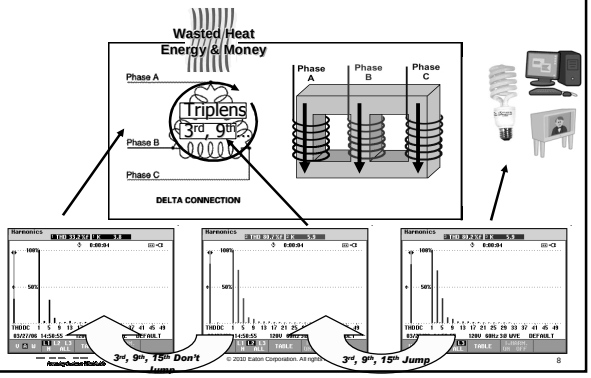
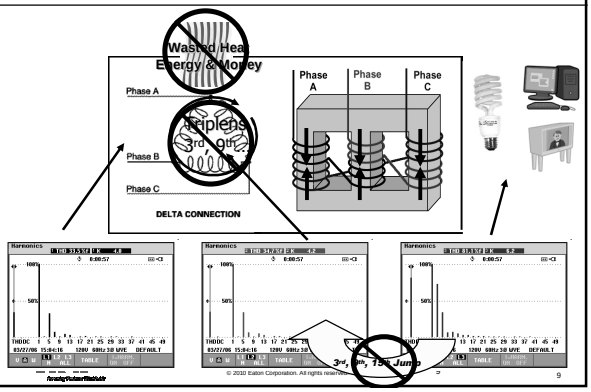


Normal Transformers with Computer Load



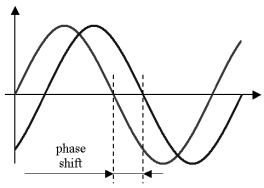
Eaton's HMT with Computer Load



Triplen Harmonic Treatment – Summary

- Triplen's are in-phase in all three phases
- Because they're in-phase, when they couple to the Primary, they circulate in the Delta winding causing:
  - extra heat
  - wasted kwh energy
  - additional losses = wasted money (24/7 for next 30+ years)
- Triplen currents are additive in the neutral
- By changing the secondary winding on the transformer, triplens don't couple to the primary, therefore:
  - *NO* extra heat
  - *NO* wasted kwh energy
  - *NO* additional losses or wasted money (savings over life of transformer as there is no maintenance to maintain efficiency - what you've bought is what you're stuck with)

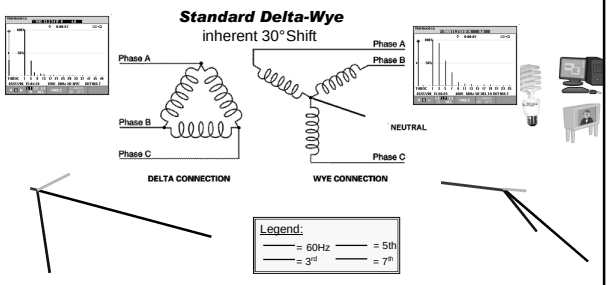
Harmonic Treatment – Phase-Shifting



Phase shifting describes relative phase shift in superposing waves. By superposing waves using different phase shifts the waves can add to (0° shift = "in phase") or ***cancel out each other (180°).***

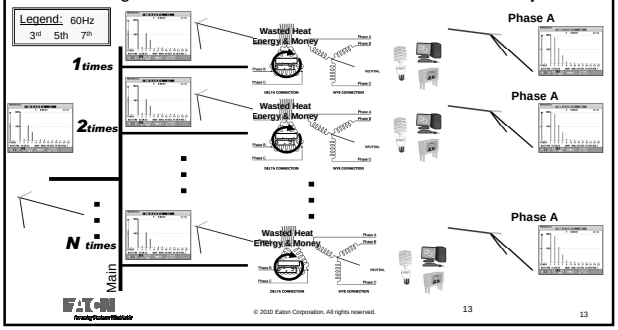
Phase shifting. (2006, June 17). In *Wikipedia, The Free Encyclopedia*. Retrieved 20:19 June 20, 2006, from http://en.wikipedia.org/w/index.php?title=Phase_shifting&oldid=59105970

What happens in a normal Delta-Wye Transformer



What happens in a normal Delta-Wye Transformer – Whole Building

BUT…since all delta-wye transformers have 30° shift – and all have same voltage reference – the 5th & 7th are ***additive on each phase.***



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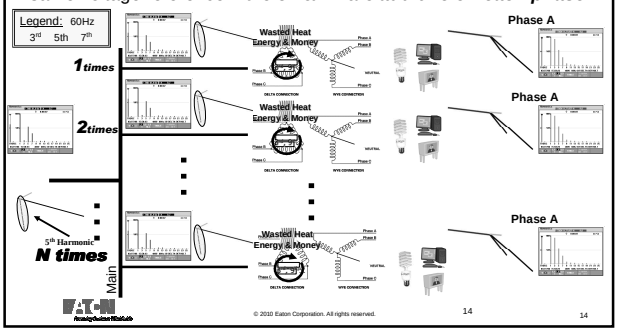

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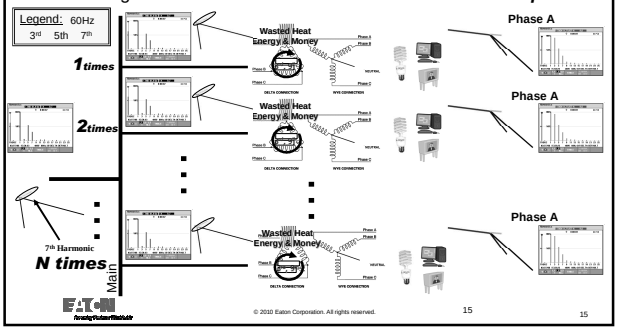
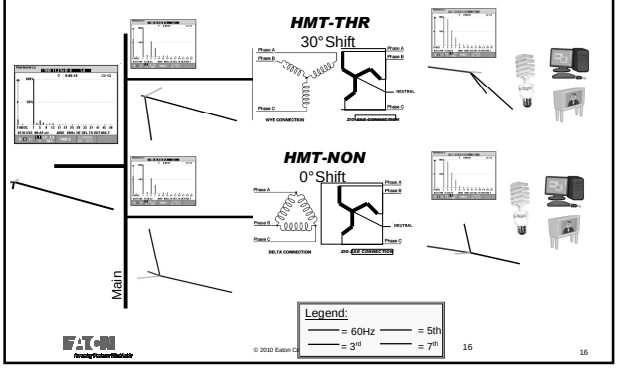


What's happens with Eaton's HMT's



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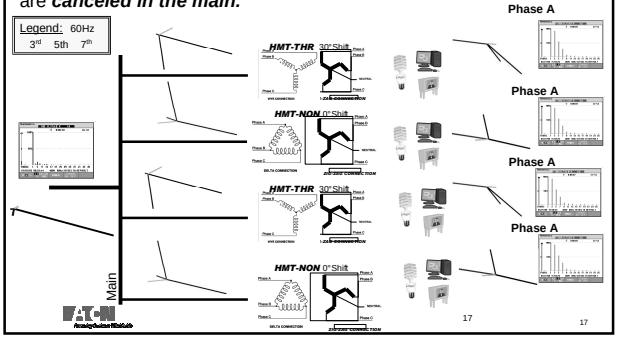
What's happens with Eaton's HMT's – Whole building

Since transformers are phase-shifted against each other – the 5th & 7th are ***canceled in the main.***



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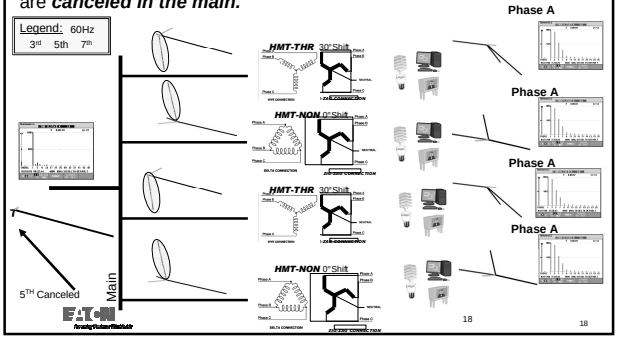

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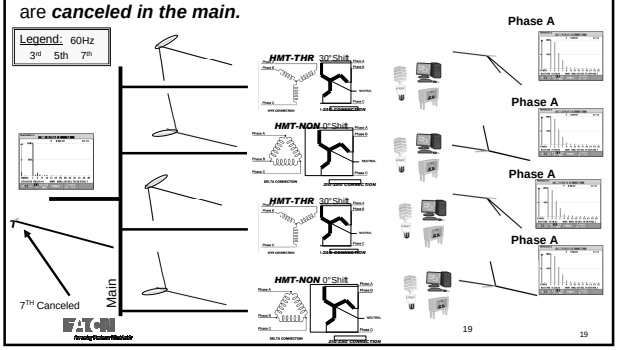

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5th & 7th Harmonic Treatment-Summary

- 5th and 7th harmonics just flow right through a transformer (therefore can't '*redirect*' them, but can *alter* them as they flow through)
- Use 5th & 7th harmonics from one area to treat 5th & 7th harmonics in another (since using already existing energy – no additional energy or money needed, as with active filtering)
- Can be used in combination with existing, standard delta-wye transformers to achieve harmonic cancellation (retrofit or expansion)

20

20

Transformer Comparison when feeding Computer Load

	Normal (Delta-Wye)	Eaton's Harmonic Mitigating Transformer
Designed For:	Linear Load (Loads of Yesterday)	Non-Linear Loads (Today's Loads)
Efficiency:	96.1%	98.3%
Heat:	Runs Hot Reduced Life	Runs Cool Long Life

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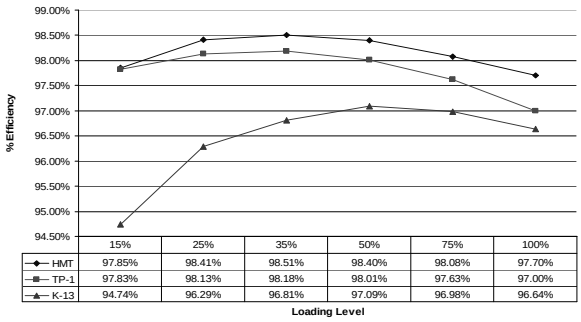
21

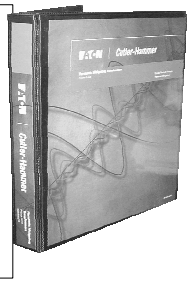
Transformer Performance Comparison



	15%	25%	35%	50%	75%	100%
HMT	97.85%	98.41%	98.51%	98.40%	98.08%	97.70%
TP-1	97.83%	98.13%	98.18%	98.01%	97.63%	97.00%
K-13	94.74%	96.29%	96.81%	97.09%	96.98%	96.64%

***Note: Standard TP-1 transformers are not UL rated for non-linear load usage without derating*

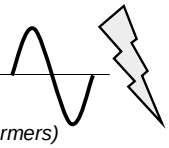
HMT Binder & CD-Rom Contents



Electronic Version available Online

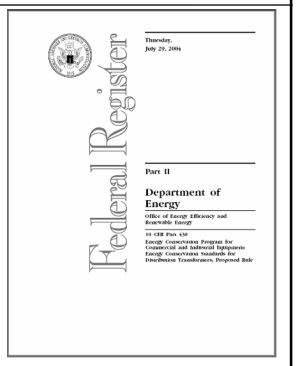
Application Bottom Line

- Use Harmonic Mitigating Transformer (HMT) in areas of high concentration (>75%) of non-linear loads
  (traditionally about 1/4 of the building transformers)



- Use CSL-3 ultra-energy efficient transformers for the rest of the building for energy savings
  (the rest of the building transformers)

CSL-3: The Eaton 'Green' Transformer


Federal Register

Thursday,
July 29, 2004

Part II

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10 CFR Part 430
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25

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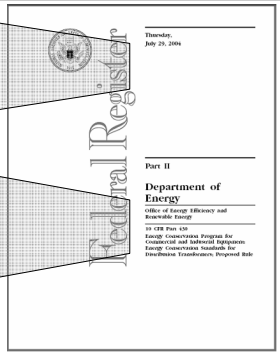
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26

CSL-3: The Eaton 'Green' Transformer

- Candidate Standard Level (CSL)
  CSL-1: least efficient = TP-1
  CSL-5: very efficient & $$$$
  CSL-3: More efficient & $
- CSL-3 transformers had 25-30% fewer losses than NEMA TP-1 (CSL-1) compliant transformers.
- May assist in earning LEED credits.

Anticipated that the CSL-3 efficiency level will become the next national voluntary efficiency level, i.e.`Energy Star®


Federal Register

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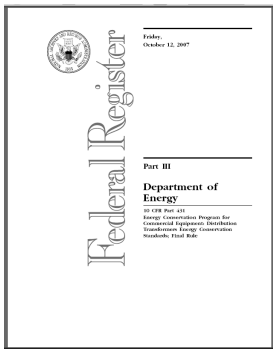
The CSL-3 'Final Rule' – Oct 2007


Friday,
October 12, 2007

Part III

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10 CFR Part 431
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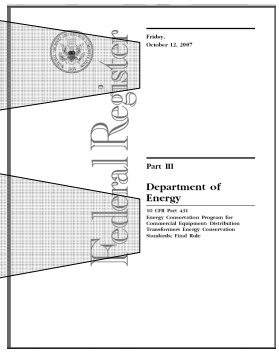
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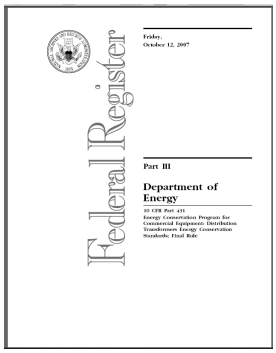
29

The CSL-3 'Final Draft' – Oct 2007

- National Standard adopted – CSL-1 (which is NEMA TP-1)
- CSL-3 Levels changed per the 'Sliding Rule' (numbers based on real transformers)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30

CSL-3 Differences in Losses vs TP-1

Transformer Efficiency (%) & Decrease Losses vs TP-1

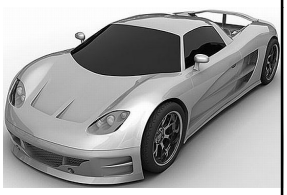
kva	TP-1	CSL-3 Draft 2004		CSL-3 Final 2007		Eaton's E3	
15	97	97.6	20%	97.97	32%	98.02	34%
30	97.5	98.1	24%	98.29	32%	98.36	34%
45	97.7	98.3	26%	98.45	33%	98.63	40%
75	98.0	98.6	30%	98.64	32%	98.71	35%
112.5	98.2	98.8	33%	98.77	32%	98.86	37%
150	98.3	98.9	35%	98.86	33%	99.00	41%
225	98.5	98.9	27%	98.97	31%	99.07	38%
300	98.6	99.0	25%	99.04	31%	N/A	N/A
			28%		***32%***		***37%***

Loaded 35% Linear Load

Efficiency Example

What if I could offer you a car that:

- Would last for 30 – 50 years
- Would require NO maintenance
- Would pay for itself every 5-7 years
- Would be the most efficient car on the road
- Runs for 24 / 7 / 365



Another Analogy - Investment

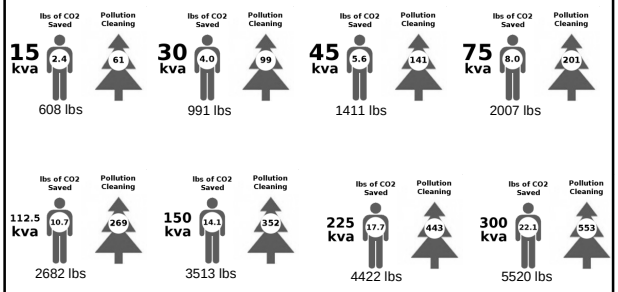
- With a 5-7 year payback of money…. that's like a 14% - 20% return on your money that starts to pay immediately.

Government Initiatives for Stimulus concerning Transformers

AMENDMENT NO.llll Calendar No.lll
Purpose: To provide rebates for qualified transformers.
IN THE SENATE OF THE UNITED STATES—111th Cong., 2d Sess.
S. 3079

1 On page 14, between lines 8 and 9, insert the fol-
2 lowing:
3 (30) QUALIFIED TRANSFORMER.—The term
4 ''qualified transformer'' means a transformer that
5 meets or exceeds the National Electrical Manufac-
6 turers Association (''NEMA'') Premium Efficiency
7 designation, calculated to 2 decimal points, as hav-
8 ing 30 percent fewer losses than the NEMA TP-1-
9 2002 efficiency standard for a transformer

Environmental Impact of E3 Transformers vs standard NEMA TP-1

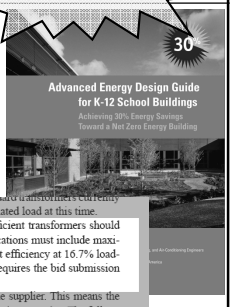


Loaded at 35% with Linear Load, per the EPA eGrid 2007 Publication

CSL-3 Transformer

- Will see increasingly in transformer specifications (such as this new ASHRAE Design Guide) as continued education is provided on energy savings opportunities within all types of buildings

Download for FREE http://ASHRAE.org



specified at one-sixth loading is 80% to 85%. This is an unregulated load at this time.

Specification of Energy-Efficient Transformers. Energy-efficient transformers should be specified using DOE's CSL-3 Standard as the basis. Specifications must include maximum no-load losses for specified transformers sizes and percent efficiency at 16.7% loading. A statement should be included in the specifications that requires the bid submission to include test data for the transformers being provided.

Electrical distribution equipment is usually provided by one supplier. This means the cost of the transformer is "buried" in the electrical distribution equipment price. The follow-

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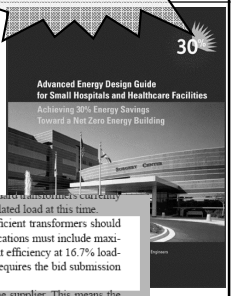

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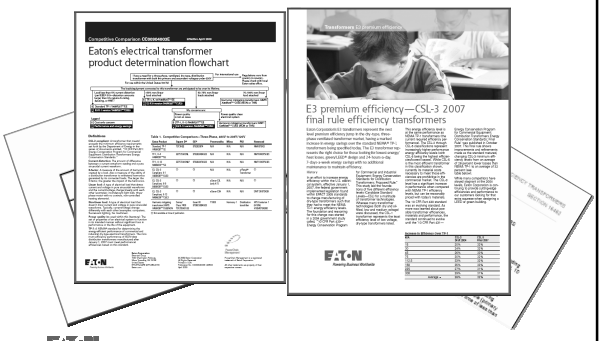
How hard is it to 'Go Green' with Transformers?

- Normally 'Green' means:
  - Additional complexity
  - Changes to the user's environment
- 'Green' transformers are a painless conversion – just a change of specification (no changes in short-circuit, wiring, breakers, kva changes, etc).
- Typically no maintenance over lifetime to maintain energy efficiency.
- 34%-41% Savings over standard TP-1

Vertical Markets

- Schools
  - Elementary, Middle, & High Schools
  - Universities – labs, computer centers, dorms
- Medical
  - Hospitals
  - Private offices with sensitive equipment
- Office Buildings
- Casinos
  - All loads are non-linear & require clean power for proper operation (no mistakes)

Literature & Submittal Support



Dry-Type Distribution Transformer - Product Determination Flowchart

Competitive Comparison **CC00904003E** Effective April 2008

Eaton's electrical transformer product determination flowchart

NEW

Regulations vary from country to country. Please check with local Eaton sales office.

For international use

I have a need for a three-phase, ventilated, dry-type, distribution transformer with both the primary and secondary voltages under 600V

For use within the United States (60 Hz)

The loads/equipment connected to this transformer are anticipated to be over its lifetime.

- Load less than 5% current distortion (per IEEE® 519—distortion amounts larger than 5% require K-rating, derating, or HMT)
  - $ Standard TP-1 V48M28T**EE
  - Q E3 K-1 version V48M28T**CUE3
- <50% non-linear load attached
  - $ TP-1, K-14 H48M28T**EE
  - Q E3 K-9 version B48M28T**CUE3
- 50–75% non-linear loads attached
  - My concerns are:
    - Power quality is not an issue
      - $ TP-1, K-13 N48M28T**EE
      - Q E3 K-13 version N48M28F**CUE3
    - Power quality clean electrical system
      - Harmonic mitigating transformers (HMT) X48M28F**CUEE (NON or THR)
- 75–100% non-linear load attached
  - Harmonic mitigating transformers (HMT) X48M28F**CUEE (NON or THR)

Legend
$ Cost only concern
Q Performance and energy savings

Questions & Attempted Answers