October 31, 2011

Mr. Richard Parker
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Subject: Analysis of M3 Compared to Amorphous Core Designs

Dear Richard:

We have examined the 25 kVA single phase Design Line 2 Pole Type Transformer to understand fundamental relationships between M3 Core Material and that of Amorphous Core. We offer these comments for your consideration for the DOE Negotiations.

I. Observations:

- **a.** Amorphous core transformers have lower core loss than M3 Silicon iron transformers but higher winding losses. At 50% load, they both have the same efficiency. At less than 50% load, amorphous core transformers have lower total losses than M3 silicon iron but that is always at night when electric power cost is at a minimum. During the day when the load peaks and exceeds 50% of nameplate load, amorphous core transformers have higher total losses than M3 transformers designed for the same efficiency at 50% load. During the day when peaking generators are running the electric power costs are the highest, sometimes hitting 3 times the night time rate and yet at that point the amorphous core transformers have higher total losses than the M3 transformers.
- **b.** Amorphous core transformers are generally more costly to build than M3 silicon iron transformers and sell for higher prices.
- **c.** Amorphous core transformers may not result in energy savings and total cost savings to the end users and in fact may result in higher energy usage and costs.

II. Assumptions

- **a.** Considerations are made at the present 2007 mandatory energy efficiency standards of transformers but the starting point does not really affect the conclusions in this memo.
- **b.** DOE Design line 2 is the 25 kVA and is most representative of single phase poles.
- **c.** The present 25 kVA mandatory efficiency for Design Line 2 is 98.91% at 50% load.
- **d.** Two designs are considered, one amorphous and one M3 and both meet the mandatory 98.91% efficiency at 50% load, and with a total allowable loss of 137.8 watts.
- **e.** The peak efficiency for each core material occurs when the core loss = the total load loss.
- **f.** For the 25 kVA, with M3, the core loss is assumed to be ½ of 137.8 watts or about 68.9 watts. The load loss at 50% load is also 68.9 watts. Hence the load loss of the M3 design at full load is 4* 68.9 or 275.6 watts. Total loss for the M3 design at full load would be 68.9 + 275.6 or 344.5 watts.
- **g.** We assumed that amorphous cores have ~1/3 the core loss of M3. Hence the amorphous transformer would have approximately 26 watts of core loss. Hence the amorphous transformer would have 68.9-26 or 42.9 more watts of load loss than the M3 design at 50% load. This means that the amorphous design would have 68.9+42.9 or 111.8 watts of load loss at 50% load or 447.2 watts of load loss at full load. Total loss for the amorphous design would be 26 + 447.2 or 473.2 watts.
- **h.** Hence the amorphous design has 68.9-26 or 42.9 watts less than the M3 transformer at no load but 473.2-344.5 or 128.7 watts higher loss than the M3 design at full load.
- i. Night time load cycles may dip to 10% of rated load at night but rise to a normal 80% of rated load several times during the day.
- j. During cold load pickup after an outage, total load often reaches 120% or higher of rated load and persists for periods of up to an hour or more.
- k. The IEEE Loading guide C57.12.91allows for up to 200% of rated load for periods of up to 30 minutes. During such periods the amorphous core has 1814.8 watts of loss while

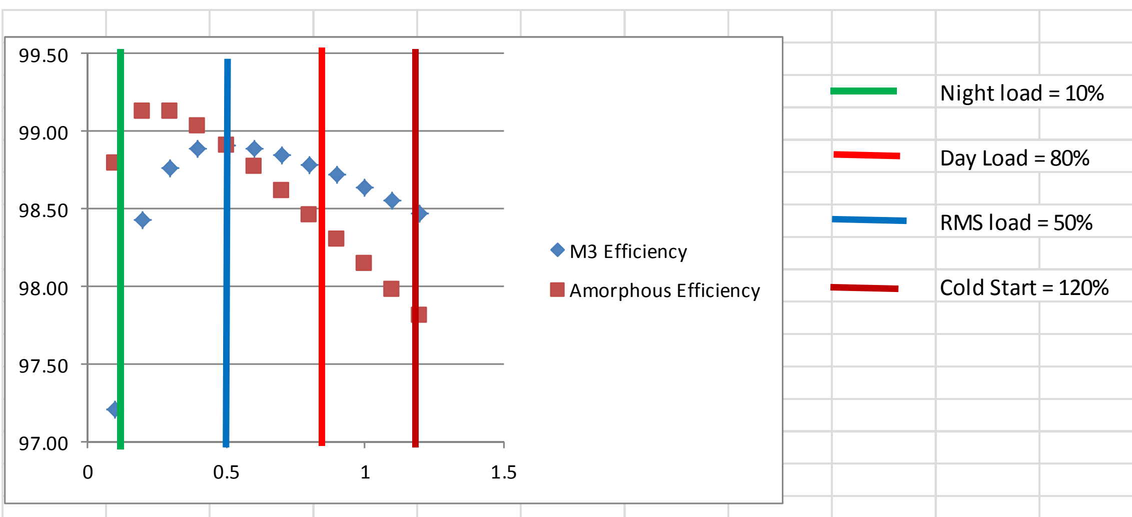
the M3 silicon iron transformer has 1171.3 watts, resulting on an added 643.5 watts or 55% greater strain to the system that requires extra generation when it is least available.

III. Graphical results of the analysis

a. Table I shows the efficiency of both transformers as a function of percent Load:

Efficiency				
0		PU Load	M3 Efficiency	Amorphous Efficiency
97.21		0.1	97.21	98.79
98.43		0.2	98.43	99.13
98.77		0.3	98.77	99.12
98.88		0.4	98.88	99.03
98.91		0.5	98.91	98.91
98.89		0.6	98.89	98.77
98.85		0.7	98.85	98.62
98.79		0.8	98.79	98.46
98.72		0.9	98.72	98.31
98.64		1	98.64	98.15
98.56		1.1	98.56	97.98
98.47		1.2	98.47	97.82

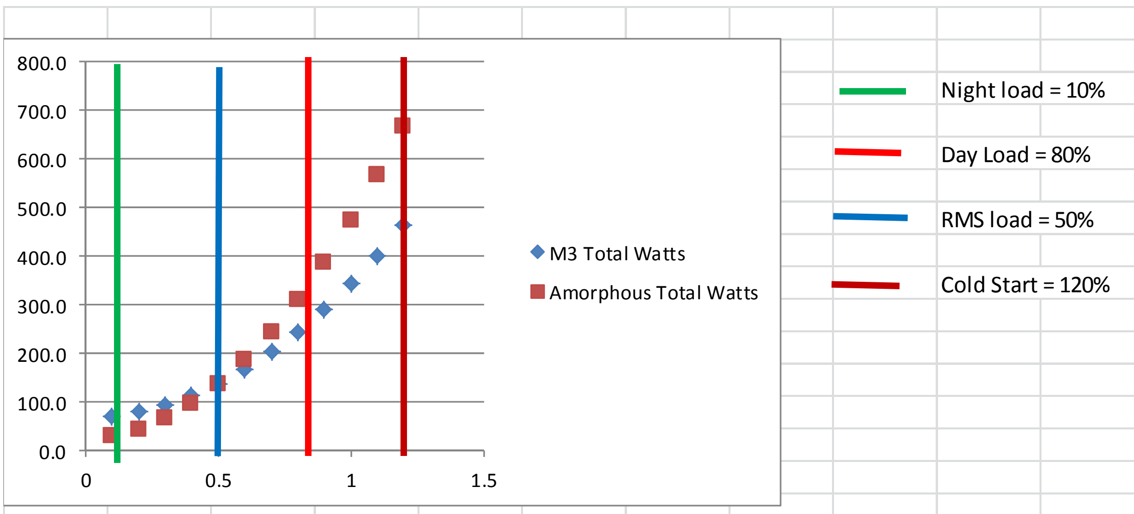
b. Graphical results of Table I



c. Table II shows watts loss versus percent load

Efficiency			Total Watts Loss	
Amorphous	M3			
0		PU Load	Amorphous	M3
98.79	97.21	0.1	30.6	71.6
99.13	98.43	0.2	44.0	79.9
99.12	98.77	0.3	66.3	93.7
99.03	98.88	0.4	97.6	113.0
98.91	98.91	0.5	137.8	137.8
98.77	98.89	0.6	186.8	168.1
98.62	98.85	0.7	244.9	203.9
98.46	98.79	0.8	311.8	245.2
98.31	98.72	0.9	387.7	292.0
98.15	98.64	1	472.5	344.4
97.98	98.56	1.1	566.2	402.2
97.82	98.47	1.2	668.9	**465.6**

d. Graphical results of Watts loss versus load



IV. Recommendations

Our recommendation continues to be to base the new mandatory efficiency standard on M3 silicon iron and not to base it on amorphous cores; for the many factors of transformer weight, size, reliability, load regulation, and even ferroresonant overvoltage problems with amorphous. Silicon iron core transformers continue to have better losses and efficiency and total economics for load growth, cold load pickup and peak demand conditions.

Very truly yours,

Philip J Hopkinson

Philip J Hopkinson, PE
President & CEO HVolt Inc

Sincerely,

Jerry L Corkran

Jerry L. Corkran
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