High Voltage Power Transformers for the Researcher
An Investigation of the Neon Sign Transformer

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Abstract

The neon sign transformer is investigated to examine just what the nameplate rating means and how the researcher might intelligently select and use these low cost sources of high voltage in their laboratory work.

Background

This paper is the result of a friendly dispute between Scott Fusare, a fellow researcher, and myself while visiting the ESJ research facility in late December of 2002. Scott contended that the neon sign transformer pretty much supplied its nameplate rated voltage and current. I noted that in my experience as a Tesla coil builder in the 90s, the transformer's magnetic shunting would never allow the transformer to satisfy its ratings before reducing the magnetic flux to a point where the voltage would precipitously drop while supplying nowhere near the nameplate rated current.

We both were fully aware that the neon sign transformer is a magnetically shunted form of transformer. In this manner, a high voltage can be applied to cold gas at reduced pressure, as in signage, causing the gas to ionize and glow. Once ionized, the internal resistance of the gas plummets and tremendous currents are demanded. In attempting to do this, the magnetic flux within the transformer core is shunted away from the windings causing a tremendous voltage reduction from the original starting voltage. The current rises only slightly and voltage is now reduced to a safe level needed to keep the hot gas ionized. This remains a rather ingenious, low cost, yet simple piece of magnetic engineering, even to this day.

Tesla coil builders have used this relatively safe and inexpensive form of high voltage transformer for years in making smaller Tesla coil systems. Other experimenters and researchers have also availed themselves of this device mostly due to its attractive cost and reduced size coupled with its modest demands on input power.

The point of contention between Scott and myself lay in the point at which the designers of the devices "turned on" the shunting through design. I turned to simple experiment as the final arbiter of the truth in this matter.

Setup

The experimental setup consisted of a custom made "load bank" designed to supply a variable load to high voltage transformers for testing purposes. (See image #1)

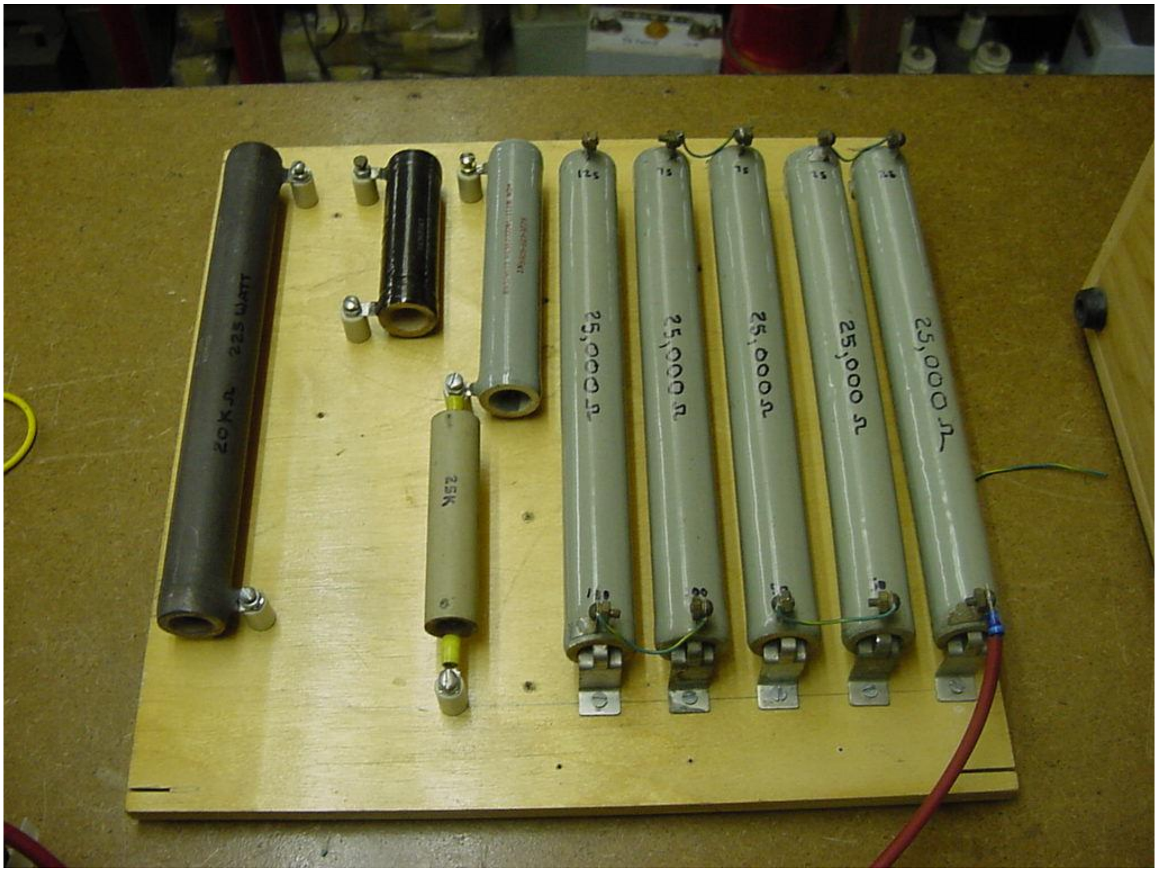


Image #1 Home made load bank. Variable 20k – 400k ohms @ up to 1.5 kilowatts

A high voltage voltmeter of extreme accuracy was used in the form of a Sensitive Research laboratory grade meter accurate to within +/- 1% over its full-scale reading. (See image #2) This meter, coupled with a high voltage rectifier and filter capacitor, allowed recording of the "peak" AC voltage output of the transformer under test. Naturally, this was converted to "rms" or "root mean square" voltages for graphing purposes. (NOTE – AC rms voltages are those normally used in the AC power business and those read by most all meters connected to smoothly varying sinusoidal power sources.) The rms value is given by the simple equation VAC rms = .7071 X VACpeak.

An AC "Variac" or variable transformer was used to vary the input voltage to the primary of the transformer under test.

A digital voltmeter was used to record the applied AC rms voltage to the primary of the transformer under test. Such meters are accurate here as the voltage measured is a smooth sinusoidal voltage. In experiments involving sparks, pulses, or irregularly varying AC waveforms, they are worthless. I see these used in all sorts of "new energy tests" where they are less than worthless. In such situations, they are deceptive and indicative of the rankest of amateur efforts.

Image #2 Sensitive Research laboratory grade high voltage meter. 30 kilovolts +/- 1%

Procedure

The load to the transformer could be varied over a wide range, but the ideal test load was arrived at by looking at the nameplate of the transformer and calculating the rated, resistive load impedance of the device. Thus, the 5 kilovolt, 30 milliamp (ma.) nameplate, by ohm's law, yielded a source impedance of 5000/. 030 or 166,666 ohms. The closest I could come to that figure was 166 kilohms and so that was used as the rated load in the test with that particular transformer. The 7.5 kilovolt, 120 ma transformer required a 7500/0.120 or 62,500 ohm load. I used a 62kohm load in this test.

Data was collected on the two transformers tested by first leaving them unloaded and increasing the input voltage in 10 volt steps up to 120 volt line voltage and recording the corresponding high voltage output of the transformer secondary. Once this was done, various loads were applied across the secondary and the process repeated to see how loading affected the output voltage. (The entire experimental setup is seen in image #3)

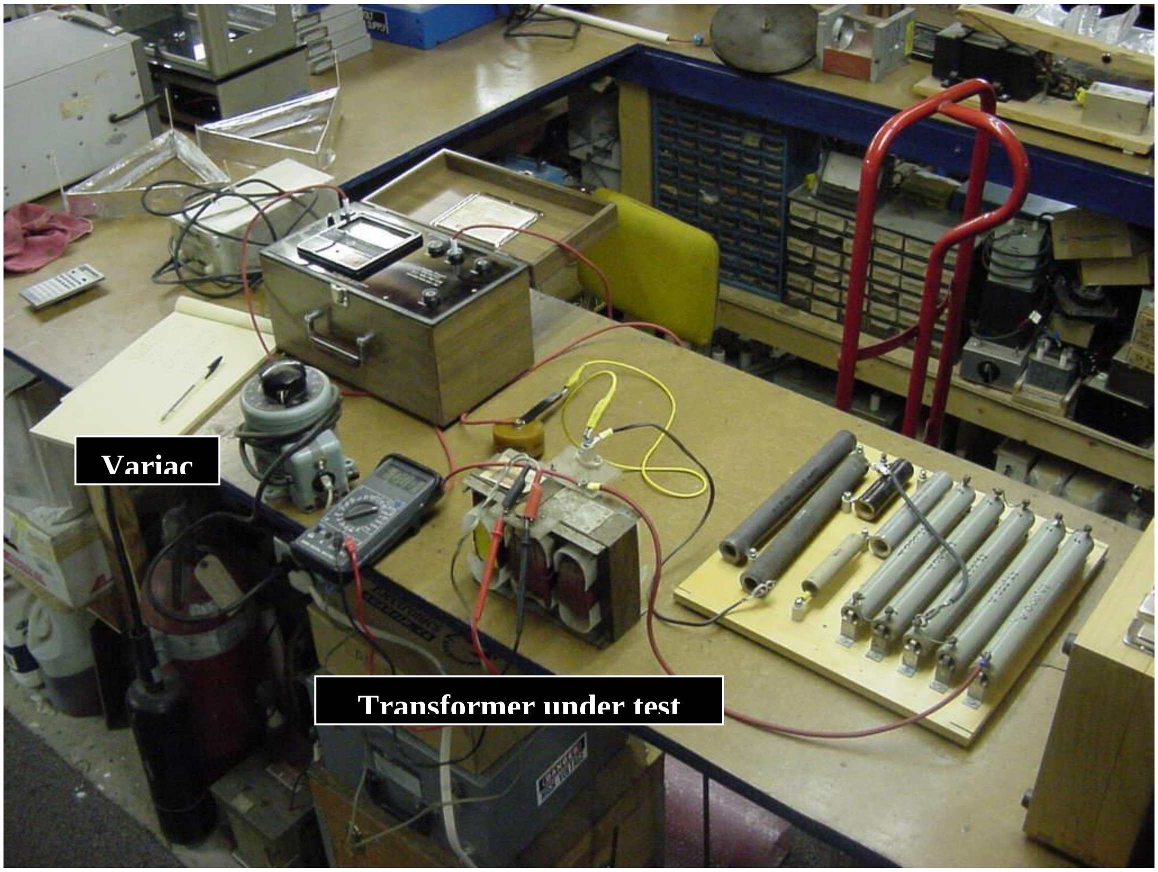


Image #3 Test setup used in these tests and experiments.

Data Section

Included in the following are two graphs of the various load lines associated with two transformers tested for this paper. It was decided to focus on the 30ma transformer in varying load tests as this is the sort most often encountered by the amateur in search of used or surplus transformers of this type. For my personal edification a “monster” high current, 120 ma neon type transformer was tested as well to see if it fared any better than the standard 30 ma units.

The data was recorded in peak kilovolts and converted to rms values prior to placing it into the Xcel spreadsheet format used to generate the graphs. Readings and “round-offs” occurred no further than to the second decimal place.

The usual care was observed in reading and interpolating the analog meter movement readings. This is an area that often “befuddles” many amateurs not used to interpreting linear scales of varying graduation factors.

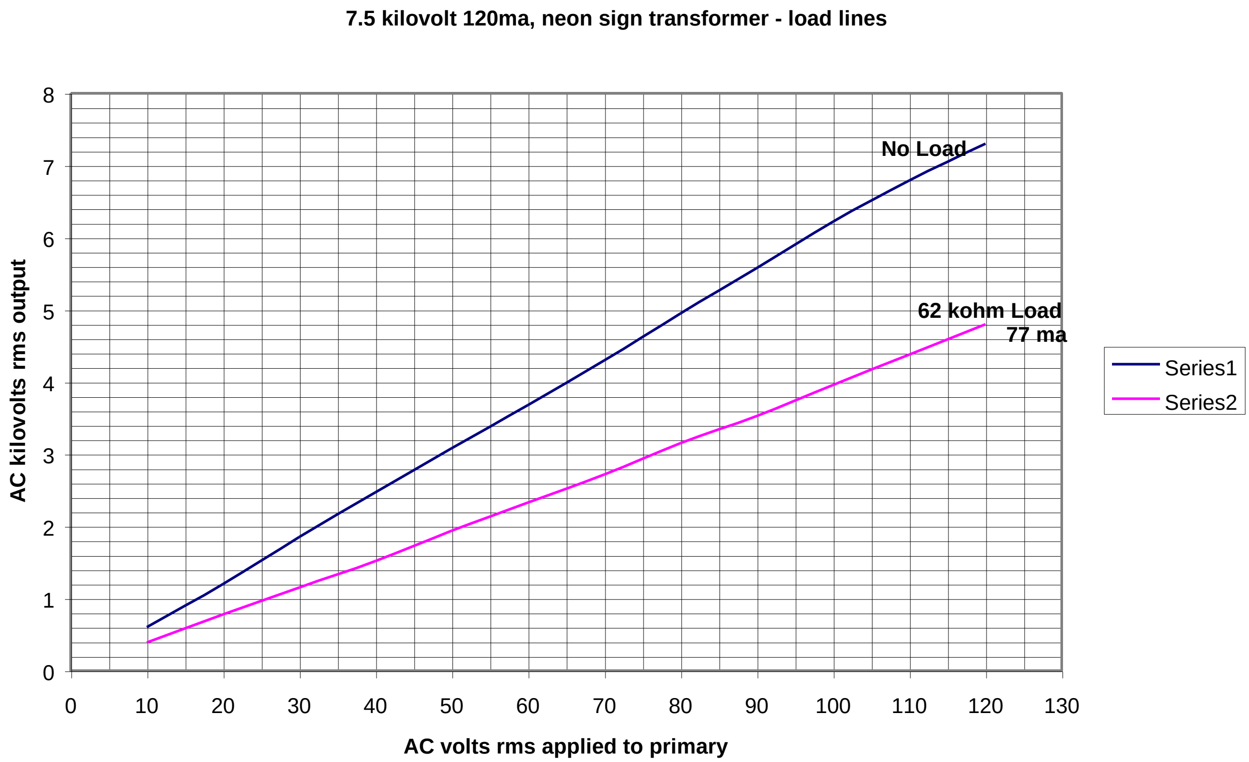
The above graph shows the results of various tests run on the 5 kilovolt 30 ma sign transformer. It can be seen that at no load, the transformer is capable of its nameplate rating of 5 kilovolts rms voltage output. Unfortunately, at rated load output, (the 166 kohm load line), the output voltage is far below rated value being no more than 3.2 kilovolts and supplying no more than 19.5 milliamps. This indicates that at full nameplate load the transformer can supply about 2/3 of the rated current and 2/3 of the rated voltage.

At the lighter loading of 232 kohms, the voltage is up to nearly 4 kilovolts while the current has dropped to 16.8ma.

At higher than rated loadings the voltage really drops at full line voltage to only 2.4 kilovolts for 24 ma draw and down to 1.35 kilovolts

Finally, at loadings in excess of rated levels it can be seen that the voltage is only 2.4 kilovolts when the current is 24ma and that only 1.35 kilovolts is available at 27ma.

Thus, only at ultra light loadings can the nameplate voltage even be approached. Likewise, full rated current can only be had at nearly 1/5 of the rated potential of the transformer.



The graph above is the result of testing a much more "beefy" neon sign transformer. It can be seen that the line for rated load mimes the lower power transformer tested above. The "2/3rds" rule applies. We can get no more than 2/3rds the rated voltage or current at rated load impedance.

Conclusions

It appears most sign transformers can be viewed in light of a "two thirds rule". No more than two thirds of the rated voltage or current may be had, concurrently, at the rated nameplate-loading factor. Furthermore, full voltage can only be obtained at zero loading. Extremely light loading can result in nearly full voltage output, but even moderately light loading can result in a rather severe drop in output voltage.

As regards current, the full rated current can only be had at the expense of voltage; leaving as little as one fifth of the nameplate voltage rating remaining at rated current.

The above proves my point to Scott and shows that the neon sign transformer must be chosen with care and regard to its rather nasty characteristic of not being able to perform up to its nameplate rating of current and voltage concurrently in any situation where continuous power is needed.

Further thoughts on the application of neon transformers

There are two configurations of neon transformers. Both involve how the ground connection is made to the secondary winding. All neon secondary windings are ground referenced. That is, their secondary winding is attached at some point to the metal case and iron core of the transformer. This is designed to be connection to electrical power ground. As such, a large bolt is always found on the case for this connection.

Small transformers of 5kv and below usually have one end of their single secondary winding attached to the case and core that must be grounded. All larger, higher voltage transformers have two secondary windings hooked in series and the central tie point of the two is always grounded to the case and core. The outer two ends then go to the high voltage insulators. This allows for the use of less insulation in the secondary windings, thereby reducing cost and physical size.

The above grounding methods impose further limits on the transformer applications, especially, as regards electronic rectification for use in DC supplies that must be ground referenced, usually at the negative polarity. A 15,000 volt neon transformer can't be bridge rectified to produce 15,000 x 1.414 = 21.2 kilovolt DC supply, and have the positive or negative lead grounded and still allow the case to be grounded. If the case ground is lifted to allow this large voltage rectification, two very dangerous situations exist. First, the case is now at 7,500 volts hot potential and could be lethal to anyone touching it. Secondly, the insulation of the primary wound on the now "hot" core may fail creating a power arc and subsequent fire hazard.

With proper grounding assured, via good practice, the 15,000 volt transformer can only be full wave rectified to no more than 7,500 x 1.414 = 10,600 volts DC with proper filtering.

While these transformers are low priced, self-limiting and well grounded by design, it is these very same features that severely limit their application as a general purpose, continuous output, power transformer. The experimenter who is well-informed and careful to design with these limitations in mind will be successful.

Postscript

It is in the nature of the experimenters to question, argue and be contentious, especially, among themselves. This paper settling the question regarding the difference of opinion between Scott and myself was done the right way. The way suggested by Benjamin Franklin over two centuries ago; "Let the experiment be done." It is not at all important who is right or wrong, for each of us has his turn eating crow. The final result will always be the truth as illuminated by empirical experiment and knowledge given to all parties privy to the results.