Have you hugged your Beam Transformer Lately?
(The rebuilding of a T/R set diode stack)

By Duane M. Evarts, CBT

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In June of 2006, KWHD TV-53’s Harris 1200UX transmitter experienced a “major-malfunction”. After some preliminary tests, Chief Engineer Ron Vincent determined that one of our two beam transformers had died.

The three-phase 460-500 volt AC input, to 24-27 kilovolt DC output transformer was manufactured by NWL in 1990 specifically for Harris. NWL was founded in the 1930's by John Nothelfer as a transformer repair shop named Nothelfer Winding Laboratories, hence NWL. For more information visit: http://www.nwl.com

Ron thought this would be another one of those “great opportunities” for me to learn the “shocking truth” about high-voltage capacitors; the purpose and typical lifespan of bleeder resistors and the proper use of the “Jesus Stick” http://www.piclist.com/techref/postbot.asp?by=time&id=piclist\2005\05\16\122645a.txt I simply had no idea just how “educational” this “opportunity” would be for me.
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Inside the oil-filled tub are a large iron-core step-up transformer; and a three-phase diode array located inside a white plastic housing mounted at the opposite side of the tank. The three-phase diode array consists of several printed circuit boards with a series of diodes and metal oxide varistors (MOV’s). Each of these boards is also known as a “diode stack”.

There were two steps involved in removing the diode array housing from the tank. First involved disconnecting the high-voltage lead wires and second, removing the plastic housing from the tank wall.

Locating some of the wires required reaching my entire arm’s length down into the oil to locate the terminals. While reaching down, I determined that there was not enough slack in these lower wires to bring them up near the top of the tank where they could be seen.
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It became obvious, that if any wires (or nuts, washers, tools, etc) ever fell to the bottom of the tank, someone would be taking an oil bath (and I knew it would not be Ron). So before removing the nuts and washers, I tied a small rope to some of the wires to keep them from sinking.

This is a good point in the story to emphasize safety. These transformer/rectifier (T/R) sets are DANGEROUS! They should never be worked on alone. Even with Ron keeping a keen eye on me and frequently discharging the massive high-voltage caps with the “Jesus stick”, I still got a pretty good jolt while disconnecting and reconnecting some of the wires on the diode array.
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A second note on safety - don’t even think about removing the tank top or any access covers while a T/R set is energized. Double and TRIPLE check that any and all breakers feeding primary power are shut off and verify that the output path has no way to have any DC return from another location. T/R sets can KILL!

Now let’s get back to the story.
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After removing the diode array it took quite a while just to clean off the oil. I lost track of how long it took before I could even begin preliminary testing and disassembly, but it was well over an hour after the getting it out of the tank.

The diode array is a polyphase rectifier, using one diode stack for each of the three phases. The schematic shows a typical three phase full-wave rectifier circuit. The only difference is that our diode stacks use several diodes each with a parallel MOV, “daisy-chained” in series to withstand higher voltages that an individual diode could never handle.

(Courtesy of http://en.wikipedia.org/wiki/Diode_bridge)
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Even before removing the first board for inspection, I saw damage to the board’s printed circuit areas as well as a few vaporized diodes and blown MOV’s.

Below is a close-up of a blown MOV. If you look to the left on the same board you’ll see another MOV with a major crack.
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Disassembly of the diode array was pretty straightforward. The next step was a more thorough visual inspection.

Yellow arrows point to multiple blown MOV’s, Red arrows show complete disintegration of printed circuit material. Almost every diode on this half of the board was defective.

At this point Ron started making phone calls to Harris about getting a new diode stack shipped overnight. This is where the story gets interesting. Harris indicated that they had a diode stack in stock and we’d have it the next day.
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Here is what they sent us. Yes, it was a diode stack, but not for “our” T/R set. We didn’t even bother to remove the bubble wrap. It was sent back the day after it arrived.

After a few more calls it was determined that Harris no longer carried individual diode stacks for our model of T/R. However they said they could still supply us with the correct and complete “three-phase diode array” for “several thousands” of dollars with a lead time of “only” two to three months! The thought of operating at less than half-power for that period of time was not an option. The next choice was to find an available (new or used) beam transformer.

This proved equally challenging in that NWL said they could not sell us a T/R set for our transmitter because of a contractual obligation they had with Harris. We would have to order the complete T/R set from Harris (with their markup) and it would still take just as long because NWL didn’t have one in stock anyway. Oh yes, let’s not forget that after shipping and installation we were now talking about several “tens of thousands” of dollars!
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Meanwhile, back on the workbench I began the process of testing every diode and MOV on the three boards. Using a homemade diode checker I determined that there was significant damage to only one half of one of the diode stacks.

“Good” diode

“Bad” diode

“Open” diode

“Shorted” diode
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Here is the board prior to “surgical intervention”.

I started doing research on part numbers and vendors. Since we had everything to gain and nothing to lose, we ordered a couple hundred dollars worth of parts and I started de-soldering and cleaning up the most impacted board.

Nobody ever got fired for taking a close up picture to aid in inserting the new diodes in the proper polarity.
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Due to the thickness of the diode leads and their very short lengths, I found it easiest to simply use diagonal cutters on the component side and then de-soldered the remains from the board. I should have bought some shares of stock in “Solder Wick”. I understand they had great earnings from sales near the end of the second quarter of 2006!

The top side of the board suffered much more damage to the printed circuit area than could be seen until after component removal
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The bottom side was in much better condition, but still had a few burns.

When the parts arrived, the diodes were identical to what was originally on the board, but the MOV’s looked very different. A phone call to CKE, Inc assured me that the new blue MOV was a compatible, direct replacement for the old black version. For more information, visit the link below.

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After removing all the defective components, some of the holes had to be re-drilled in order to allow the new parts to be inserted.

I found a drill bit small enough for this kind of board work at Lowes. The bit was not available by itself. I had to buy a set of bits to get the one I needed. If you ever have to do this kind of work, I hope you have a very small drill press.
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The parts arrived overnight and the process of inserting the components began.

In only a few hours after the parts arrived, the board was fully populated, soldered and given a final diode test.

The resurrected board just before trimming the leads
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The board’s bottom side with the leads trimmed.

The other two rectifier boards somehow escaped the catastrophic failure detailed in this article. One of those boards had a couple of marginal diodes that were replaced along with their respective MOV’s. As I recall, the third board had no failed components at all.

The array was put back together, reinstalled in the tank and put on-line less than five days from original failure. And I’m pleased to say has been happily “humming” ever since. Of course it is worth mentioning again that I was also shocked in the process of putting one of the wires from the transformer back on!

I have such vivid and fond memories of this experience that I’m hoping to assist Ron at midnight on February 17th 2009 to once and for all shut this beast down for good!

For further reading I recommend:
http://en.wikipedia.org/wiki/Transformer_oil
http://en.wikipedia.org/wiki/Rectifier
http://en.wikipedia.org/wiki/Varistor
http://www.piclist.com/techref/postbot.asp?by=time&id=piclist\2005\05\16\122645a.txt