The Jersey Broadcaster

NEWSLETTER OF THE NEW JERSEY ANTIQUE RADIO CLUB

April 2025 Volume 31 Issue 4

The *Jersey Broadcaster* is distributed to members of the New Jersey Antique Radio Club via email as a PDF file. Back issues of many of our newsletters are available on the club's website: www.njarc.org/broadcaster/

Meeting Notice

Our April meeting will be held at Bowen Hall, Princeton University on Friday, 4/11. At our April meeting, we'll feature "Show & Tell" and "Hints & Kinks" by YOU our members. Bring in an interesting item from yyour collection and tell us all about it. Or regale us with a story about your favorite restoration "kink" that makes your project easier or better. We plan to livestream the meeting on YouTube at youtube.com/user/NJARC. Directions can be found on Google Maps at https://bit.ly/4jZe8XI.

Meeting Review

Our March meeting featured a look at the technology behind the "Iron Dome" defense system, presented by the Chairman of InfoAge John Cervini who spent his career in defensive weaponry.

Many of our meeting presentations are available on the club's YouTube channel https://bit.ly/3yZ5yoR.

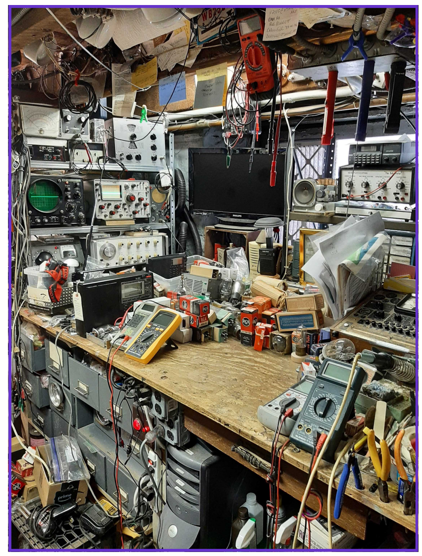
Calendar of Events

April 11: NJARC monthly meeting, Princeton
April 15: DVHRC monthly meeting, dvhrc.com
April 18: HARPS monthly meeting, Suffern NY
April 25-27: International Marconi Day, InfoAge
April 26: NJARC Spring Repair Clinic, InfoAge
May 9-10: Kutztown Radio Show, dvhrc.com
May 16: NJARC monthly meeting, InfoAge
May 23: HARPS monthly meeting, Suffern NY
June 10: DVHRC monthly meeting, dvhrc.com
June 13: NJARC monthly meeting, Princeton
June 20: HARPS monthly meeting, Suffern NY
July 8: DVHRC monthly meeting, dvhrc.com
July 11: NJARC monthly meeting, Princeton
July 15: HARPS montly meeting, Suffern NY
July 26: NJARC Summer Swapmeet, InfoAge
August 8: NJARC monthly meeting, Princeton
August 23: NJARC Summer Repair Clinic, InfoAge
September 12: NJARC monthly meeting, InfoAge
September 19-20: Kutztown Radio Show
October 7-11: AWA Conference, Henrietta NY
October 10: NJARC monthly meeting, Princeton
October 25: NJARC Spring Repair Clinic, InfoAge

From the President's Workbench

Greetings Fellow Enthusiasts!

This is a review of our successful Spring Show at the Parsippany PAL building on Saturday, March 22nd. This was one of the best NJARC Hamfest/Swapmeets in recent history.



The President's Workbench.

It was a successful event largely because of those NJARC members who were giving of their time for: table and chair setup, entrance fee collection, canteen work, 50/50 ticket sales, vendor fees collecting and the ever-popular "walk-around-auction" event.

This is a list of the dedicated club members who, without their help, our Spring, Summer and Fall Hamfest/Swapmeet shows would cease to exist! So special thanks to: Fred, Judith, Jerry, Jon, Darren, Matt, Dave, Vince & Roxanne from New Rochelle, New York (note from editor: and Rich, always the first to arrive and the last to leave!)

For an interesting review of the show, check out YouTuber Scoutcrafter's visit to our event at 15:43 minutes into his video: https://bit.ly/4cq46v6

Check it out, it's a lot of fun!

– Richard Lee Pres. NJARC

(Swapmeet photos on next page.)

THE JERSEY BROADCASTER is the newsletter of the New Jersey Antique Radio Club (NJARC) which is dedicated to preserving the history and enhancing the knowledge of radio and related disciplines. Dues are $25 per year and meetings are held on the second Friday of each month either at InfoAge or at Princeton University. Neither the editor nor NJARC is liable for any other use of the contents of this publication other than for information.

President's Workbench
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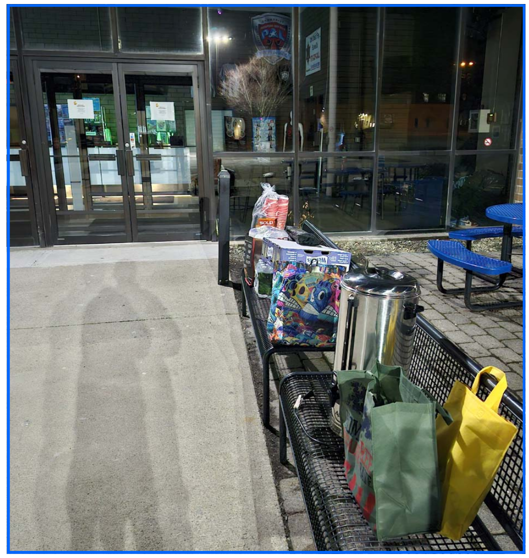
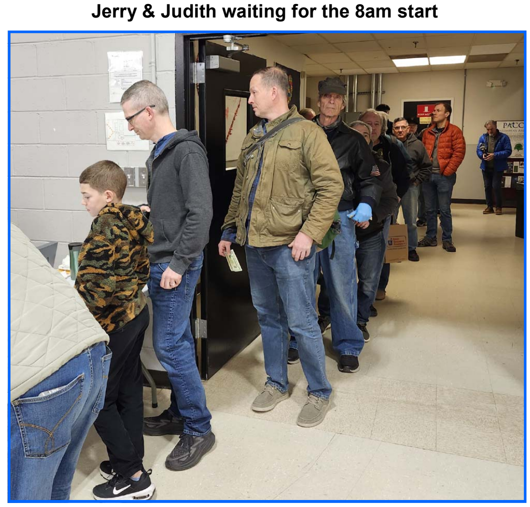


6:09 AM: waiting for access

Jerry & Judith waiting for the 8am start

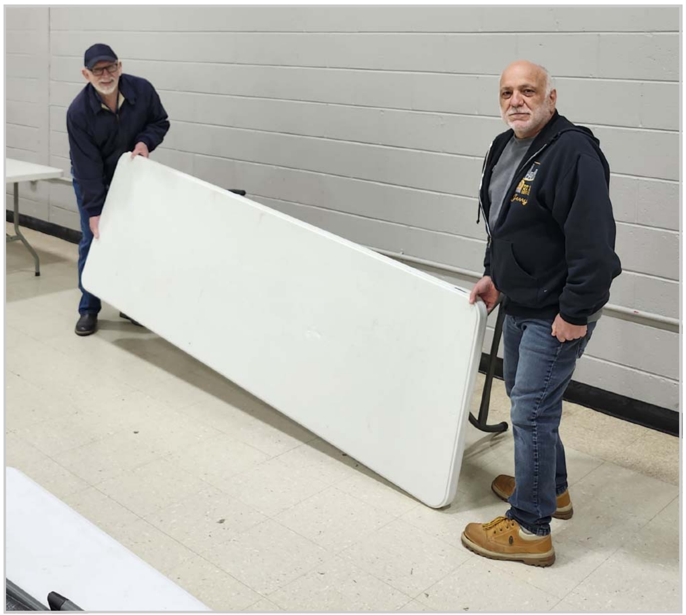


It's 8:01 and here come the buyers!

Photos continued on next page.

President's Workbench
(Continued)

More Photos from the Hamfest / Swapmeet



Vince & Jerry set up additional tables

The PAL sign that the administrator said cannot advertise our club shows: lightening strike. (Coincidence?)

The hall fills up fast

The 'D' of [JD Auction Services]() working the walk-around auction

Judith & Fred sorting the Radio Bagels and Radio Coffee

A Deep Dive Into Rectifiers Used in AC Powered Tube Radios

By Jim Whartenby

The main purpose of this article is to discuss the disadvantages of vacuum tube and selenium rectifiers in providing plate voltages in radio receivers and other devices. Although vacuum tube rectifiers are not, as far as I know, in short supply, selenium rectifiers are. Even if New Old Stock (NOS) Selenium rectifiers can be found, they are not to be trusted as the test data presented here shows.

Vacuum tube rectifiers

Before the use of selenium to supply B+ voltage, vacuum tube rectifiers were used in AC line-powered radios. There are some often-overlooked limitations to their use. One was the limited average current that a vacuum tube rectifier can safely handle without damage to it's own cathode. Other limitation were the excess heat in the radio cabinet due to heating the rectifier cathode and the IR loss due to the combination of the rectifier plate resistance and the B+ current.

Each vacuum rectifier type also has a unique maximum non-repetitive current rating. Typically some 5 to 10 times the normal operating B+ current. The duration of the pulse is also limited to about 12 AC voltage cycles or some 200 milliseconds. This "hot switching current," as it is called, is caused by the initial charging current of the power supply filter capacitor. The larger the value of this filter capacitor, the higher the hot switching current and the shorter the capacitor charging time. Both of these factors will stress the tube rectifier cathode.

To prevent damage to the vacuum tube rectifier cathode because of this high current, some means of reducing it to a safe level may be necessary. Usually the wire resistance of the power transformer primary and secondary and the vacuum rectifier plate resistance is sufficient to limit this surge current to a safe level but since consumer radios are designed with cost in mind, some shortcuts may have been taken.

Additional circuit resistance will limit this charging current so that it does no harm to the rectifier cathode. The Radiotron Designers Handbook mentions this problem on page 99. How to determine the power transformer winding resistance and what additional resistance may be needed to limit the peak filter capacitor charging current are discussed in detail.

The rectifier tube's cathode is sized to supply the needed cathode current. Because of this, the vacuum tube rectifier has the largest cathode in a radio receiver. It takes a lot of power to heat a large cathode to emit electrons. Ten to fifteen watts of heat is not uncommon. Once the heat has done it's magic, it exposes nearby components to this heat. Heat is the enemy of component reliability. The hotter the environment of the component, the more likely it is to fail.

Since the rectifier plates are located a distance away from the hot cathode, the plate is not able to emit electrons. The metal plates of most vacuum tubes are dark in color due to processing, which helps reduce their operating temperature. This situation prevents a reverse bias current from flowing when the rectifier plate is negative with respect to the positive cathode. This point of a reverse current is important when we next examine the operation of the selenium rectifier.

In summary, the vacuum tube rectifier is inefficient, it requires more power to operate than other rectifier types. This inefficiency adversely affects other components in the radio due to the heat needed by the cathode to emit electrons. Waste heat is also generated in the rectification process due to the IR loss produced by the rectifier plate resistance and the cathode (aka plate) current. This voltage drop can be as low as 10 volts or as high as 60 volts or more when the rectifier is operating at it's current limit. There is also a limit to the average cathode current and to the peak cathode current that it can safely supply without affecting the rectifier's long-term life.

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A Deep Dive Into Rectifiers Used in AC Powered Tube Radios
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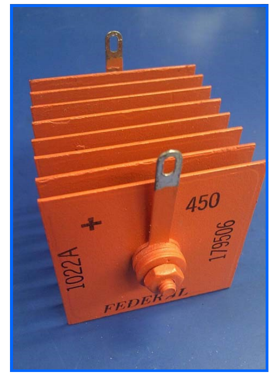
Selenium Rectifiers



On the plus side, the selenium rectifier does not require an additional source of power for operation. This eliminates some 10 to 15 watts of heat that would be needed by the tube rectifier cathode. The selenium rectifier is also smaller so it is easily tucked away under the chassis. The IR voltage drop is also much lower in selenium rectifiers. Larger values of filter capacitors are common.

Selenium rectifiers still suffer somewhat from B+ current limitations as does the vacuum tube rectifier but to a lesser extent. Controlling the surge current is done in the same manner as it was in vacuum rectifiers by adding a series resistance as needed. This surge resistor can be sized, power-wise, to act as a fuse in the event of total selenium rectifier failure. See below, Selenium Failure Mode.

Each selenium rectifier cell in a stack will have a typical forward voltage drop of one volt for a reverse voltage rating of 25 volts or more. A stack of selenium rectifiers suitable for direct operation off of the AC line will require a series stack of some 5 or 6 Selenium cells depending on the cell reverse bias withstanding voltage. So the forward bias voltage drop is between 5 to 6 volts and the nominal reverse bias withstanding voltage is in the order of 150 volts under a continuous reverse bias condition.

One added complication, not seen in a vacuum tube rectifier, is that when the selenium rectifier is reverse biased it will allow a small reverse current to flow. This is a new issue since this reverse leakage current does not exist in vacuum tube rectifiers. So now there are two power loss mechanisms in the selenium rectifier. A forward bias IR loss and a reverse bias IR loss.

For a selenium rectifier rated for 65 mA and operated at this level, the theoretical minimum forward power loss is 0.065 amps x 6 volts = 0.39 watts. If the reverse current is 2 mA and the voltage across the reverse biased stack is 340 volts then ideally, the reverse power loss is 0.68 watts.

The 340 volts is derived from the peak voltage across the filter capacitor, that is 120 volts RMS times 1.414, which is equal to 170 volts peak. When the selenium rectifier is reverse biased, then the anode end is at minus 120 volt RMS, which is also minus 170 volts peak. The combined voltage across the selenium rectifier is then 340 volts peak to peak. The selenium rectifier is providing B+ long before the vacuum tubes in the rest of the circuit are able to draw current from the power supply.

The selenium rectifier failure mode is when the forward bias junction resistance increases, thus dropping a higher IR voltage, or the reverse bias resistance decreases and causes a higher leakage current to flow. Either of these or a combination of both will cause an increase in heat dissipation in the selenium rectifier. This heat will, in time, cause a further increase in the losses, resulting in eventual selenium rectifier failure. If the current limiting resistor power rating is sized with no power reserve, it should fail as an open circuit before the selenium rectifier fails completely, thus acting as a fuse.

Rectifier testing

The following list is of seven selenium rectifiers tested for this article. They appear to be either 75mA or 100mA units, depending on the whim of the manufacturer. All are one-inch square and are mostly used units. Some are obviously defective, so they represent what is to be expected when working on a radio using selenium rectifiers. Three were graciously provided by Paul Mondok for this article. Thanks Paul! Two additional rectifiers were also tested. One was a NOS 500mA selenium rectifier, and the other was a NOS silicon rectifier.

The test set consisted of a Variac®, a home-built DC power supply that I usually use for filter capacitor reforming, a 1 ohm 1 watt resistor in series with a 1k 10 watt resistor which was at hand and three DVMs. The 1 ohm resistor was used to monitor current, the 1k resistor was the simulated B+ load resistance. No rectifier was installed between the two resistors during the setup calibration.

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A Deep Dive Into Rectifiers Used in AC Powered Tube Radios
(Continued)

The Variac® was adjusted for a current of 65mA, or more precisely, 65mV across the 1 ohm resistor. The Variac® was not adjusted for the remainder of each forward or reverse bias test. The DVM across the 1k resistor also read 65 volts. The third DVM was placed across the rectifier to measure rectifier voltage drop. Each of the rectifiers was then installed, one at a time, between the two resistors and tested for forward voltage drop. Reverse leakage current was tested by setting the Variac® for minus 275 volts across the rectifier when installed in **Selenium Rectifiers**

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I forward	V diode	I reverse	V reverse	R forward	R reverse	R ratio
43.3mA	28V	0.5mA	-268V	647 ohms	536k	828:1
57.5mA	8.9V	50mA	-190V	155 ohms	3.8k	25:1
60mA	5.5V	7.0mA (1)	-250V	92 ohms	35.7k	389:1
60mA	5.3V	9.0mA	-250V	883 ohms	27.8k	315:1
53.5mA	14V	2.2mA	-267V	262 ohms	95k	363:1
40.6mA	30V	2.8mA	-266V	739 ohms	95k	129:1
55.2mA	**13.5V**	**0.9mA**	**-270V**	**245 ohms**	**300k**	**1.23k:1**
60mA	5.4V	14mA (2)	-245V	90 ohms	17.5k	194:1
64.6mA	0.76V	0.05mA (3)	-272V	12 ohms	5.4Meg	461k:1

(Notes)
(1) NOS selenium rectifier, no evidence of solder on tabs
(2) 500ma selenium rectifier, NOS in the original box
(3) Silicon diode, 1N4007 or equavelent

to a lesser extent. Controlling the surge current is done in the same manner as it was in vacuum rectifiers by adding a series resistance as needed. This surge resistor can be sized, power-wise, to act as a fuse in the event of total selenium rectifier failure. See below, Selenium Failure Mode.

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The 340 volts is derived from the peak voltage across the filter capacitor, that is 120 volts RMS times 1.414, which is equal to 170 volts peak. When the selenium rectifier is reverse biased, then the anode end is at minus 120 volt RMS, which is also minus 170 volts peak. The combined voltage

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A Deep Dive Into Rectifiers Used in AC Powered Tube Radios

(Continued)

The legend of operating vintage radios on today's AC line voltage

Just about all comments on this subject found in magazine articles and on the internet advise one to either use a Variac® or a bucking transformer to reduce the present 122 or so VAC line to 117 volts. Usually, it is pointed out that the line voltage that was available back in the day when the radio was designed was much lower than what is found today. Creeping line voltage is said to adversely affect the operation of the set in question. Component stress is usually mentioned as a secondary consideration.

A quick check of Rider's Perpetual Troubleshooters Manual, Volume 1 will show that the above assumptions are in fact, wrong. Volume 1 covers battery sets up to and including the AC line-operated battery eliminators and early AC line-operated radio receivers available on or before 1931.

Checking the schematics of the early Philco Battery Eliminators and the later AC sets such as what is found on Philco pages 1-17, shows that the operating voltage range 95 years ago was 105 to 125 VAC. The tube voltage chart on the above page does indicate that the voltages listed were taken at a line voltage of 115 VAC. It should be noted that the average of 105 and 125 is indeed 115. So the early Philco sets were designed to work at a full line voltage range greater than what is available today.

Another check of the early RCA radio sets like the R-15, which was made in 1931, tells a similar story with the line voltage range of 105 to 125 VAC. The exception with these RCA sets is that the power transformers have an 110 and 120-volt tap so optimum set operation can be easily achieved. See RCA pages 1-14. The Radiola 17 schematic found on later pages shows the same AC line voltage range with the same power transformer taps.

If the available AC line voltages ranged from 105 to 125 VAC, why are later-built radios labeled 115 VAC? Well, the National Electrical Manufacturers Association (NEMA) published a pamphlet on Radio Standards in 1927. In which they proposed the following:

Ratings

Input Voltages — Socket-Power Devices.

333-311 It shall be standard to rate socket power-devices at 115 volts and to design socket-power devices to function over the range of input voltages of 110-6 per cent to 120+6 per cent.

Adopted Standard 3-16-1927.

110 volts minus 6% is 103.4 volts, and 120 volts plus 6% is 127.2 volts. The average of these two limits is 115.3 volts. At some later date the above range was simplified to 115 VAC +/- 10% which closely agrees with what is found in Rider's, Volume 1, as shown above.

Over the years, the 115-volt line volt convention was changed to 117 +/- 7.5% around 1942 and later to the present 120 +/- 5% in 1954. In all cases, the upper end of each is 126 volts, give or take a volt for rounding error. The only voltage that has actually changed is the lower voltage limit. It was raised from 104 to 108 to the present 114 volts. The year when the radio industry actually adopted the 117-volt convention seems to be lost to history. I checked Riders Volume 25 (1955) and found line voltages of 115, 117 and 120 AC on various manufacturers' schematics. Oh, well! So much for line voltage standards!

What to do when changing from a vacuum tube or selenium rectifier to a silicon diode

Since the 115 line volts convention has a +/- 10% tolerance and the 117 line volts convention has a +/- 7.5% tolerance, any vintage radio is already capable of operating from a 120 VAC line. But doing so will most likely increase the heater and/or the B+ voltage provided by the power transformer. The real question is by how much and is it a concern?

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A Deep Dive Into Rectifiers Used in AC Powered Tube Radios
(Continued)

The +/- 10% line voltage tolerance is also the tolerance of all 6.3 volt vacuum tube heaters. I feel that the vacuum tube heater operating voltage is more critical then the B+ operating voltage. Operation much above 6.3 volts will have an adverse effect on vacuum tube life. This is well known and is mentioned in the various tube manuals. Lowering the heater voltage will extend vacuum tube life and also reduce some of the 60 cycle hum that originates in the vacuum tube due to heater-cathode current leakage.

Option 1

Do nothing as long as the power transformer heater voltage is below 6.9 volts. This is the upper voltage spec for tube heaters. When selenium rectifiers are replaced by silicon, the B+ voltage increase is minimal, some four volts. It should be noted that there is no longer a need for a current limiting resistor since silicon diodes are much more robust than vacuum tube or selenium rectifiers. All of the 1N400X series of silicon rectifiers are rated for 30 amps of surge current for half an AC cycle. This is well above what is demanded by an uncharged filter capacitor. By the way, the initial filter capacitor charging current does no harm to the capacitor. The current limiting resistor is used solely to protect the rectifier, not the filter capacitor.

Option 2

Acquire and use a Variac®. This is an expensive proposition; even a used Variac® is expensive. It is too easy, in my opinion, to inadvertently bump the knob on the Variac® and change the set voltage. So you should occasionally check it for the proper setting to hold the input voltage steady.

Option 3

Use the now available 5-volt rectifier heater winding to buck the line voltage down some five volts. This will reduce the power transformer's primary voltage and all secondary voltages. The main benefit here is that no further adjustments are necessary. Whatever the line voltage is, the power transformer's primary sees five volts less. A word of caution: it is just as easy to wire the 5-volt winding in a boost configuration, so check the wiring before you finish the final soldering!

Option 4

Add a 10 or so ohm 10 10-watt power resistor in series with the power transformer's primary winding to reduce the primary voltage to the desired level. To do this properly, you will have to measure exactly how much current the primary of the power transformer is drawing when the radio is playing normally. Then, you can calculate the exact resistance needed to drop the line voltage to whatever value you desire. This is the easiest method of reducing the line voltage, especially if there is no five-volt heater winding in the power transformer.

I tend to ignore a moderately high B+ voltage. If the increase in B+ is at or below about 10%, then little harm is done. Most vacuum tubes used in radios are pentodes. Pentodes are very tolerant of variations in B+ since the plate current is set by control grid bias. Plate voltage has little effect on plate current in the pentode. Pentode curves found in tube manuals are essentially flat horizontal lines. This indicates that the plate current is, for all practical purposes, a constant for any plate voltage above the knee in the curves. In other words, a pentode is effectively a constant current source.

The effect of a higher B+ is that any plate load resistor has a little more voltage across it. The additional heat generated by the increased B+ voltage in the various plate circuits is dwarfed by the power savings gained by eliminating the need for the rectifier heater winding in the power transformer. The power transformer will benefit from the lower power demand by operating a bit cooler and will last much longer, as will other components in the radio.

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A Deep Dive Into Rectifiers Used in AC Powered Tube Radios

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In summary, replacing a vacuum tube rectifier with silicon will reduce the operating temperature inside the radio cabinet and reduce the power requirements of the power transformer. Replacing a selenium rectifier with silicon results in a four-or-so-volt increase in B+ voltage; nothing to worry about. If you are uncomfortable with the resulting higher B+ voltages, the various methods mentioned above or a combination of several can be used to reduce the voltages to a level that you are comfortable with.

A last note of caution. It is tempting to increase the filter capacitor value to something much higher than the original capacitor value to reduce B+ ripple. In doing this, the capacitor charging current will increase, and the duration of the current pulse will decrease. This will increase the IR loss in the power transformer's high voltage winding and increase the heat produced by the power transformer. This will stress the power transformer in an unforeseen way. In an AC/DC set, this is not an issue.

References:

Metallic Rectifier Design and Application by Julian Loebenstine
http://www.tubebooks.org/file_downloads/selenium.pdf

Metallic Rectifiers and Crystal Diodes (searchable) by Theodore Conti
https://www.worldradiohistory.com/BOOKSHELF-ARH/Technology/Rider-Books/Rider-313-Metallic-Rectifiers-And-Crystal-Diodes-Theodore-Conti.pdf

Radiotron Designers Handbook (searchable) edited by F. Langford-Smith
https://www.worldradiohistory.com/BOOKSHELF-ARH/Technology/RCA-Books/RCA-Radiotron-Designer%27s-Handbook-4th-Edition-1953.pdf

Rider's Perpetual Troubleshooters Manual
https://www.worldradiohistory.com/Rider-Manual.htm

New Radio Books

By John Stoll

I have recently come across a series of newly published books that seem like they might have value to the vintage radio hobbyist. The books are by Richard L. (Dick) Whipple and have publication dates of 2023 and 2024. The books contain circuit explanations and breakdowns as well as pictures and are well written. They seem designed to be most useful for the neophyte radio hobbyist, but might be of interest to all.

The books are available on Amazon. The author offers a number of radio and audio books, with prices from $8.99 to $16.99. Some of our members already have at least one of them.

The following link should allow you to peruse the publications: https://bit.ly/4lpSHQ4.

I have purchased 5 of Whipple's books and I feel they would be good resources. Glancing through them, all look to contain useful information. Books such as these, published recently with a mind towards newer troubleshooting gear, should help the newcomer feel more confident. For example, the books recommend a Jameco Isolation Transformer and include the specific part number for ordering.

This series joins the long list of books targeted to the vintage radio hobbyist. You might want to consider adding them to your bookshelf.

New Radio Books

By John Stoll

Don't forget: the IEEE Armstrong exhibit "Unseen Signals: E. Howard Armstrong's Radio Revolution" at the National Museum of Industrial History in Bethlehem PA runs until the end of April. More information is available on the NMIH website: https://bit.ly/4jtnnyb.