RECTIFIER SELECTION, OPERATION & MAINTENANCE

Presented by
Marty Iozzo

GENERAL CORROSION CORPORATION

What Is A Rectifier and What Does It Do?

- **It has been established that DC electricity will generate corrosion, and corrosion in turn will generate DC electricity. Therefore, it is possible to prevent corrosion by the use of DC electricity**
- **A Direct Current passing *from* a structure will cause corrosion, and a Direct Current impressed *onto* a structure will stop corrosion**
- **The Rectifier is used to deliver – *or impress* – a Direct Current onto a structure**
- **The Rectifier has two functions:**

  1. **To transform incoming line voltage (AC) provided by the utility company to a usable voltage, and**
  2. **To convert the usable AC voltage to Direct Current (DC) to be used for cathodic protection**

When Selecting Your Rectifier….

- Designed for rugged unattended service
- Cooling options
- Cabinet options
- Input – AC Power

- Output – DC Power keeping possible future requirements in mind

What's the Perfect Rectifier for Me?

- **Constant Current**

  Maintains a constant current output by adjusting the voltage as site conditions fluctuate

- **Auto Potential**

  Adjusts the rectifier output to maintain a desired structure-to-soil potential

- **Manual Tap (Constant Voltage)**

  Set it and forget it

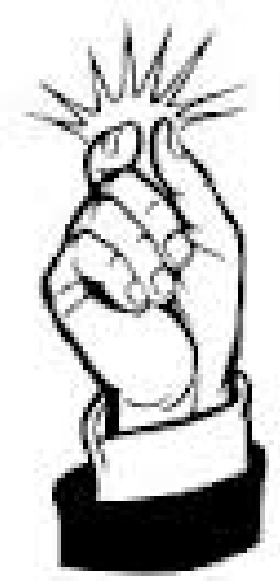
Unpacking and Installing your Rectifier

- Check for freight damage
- Tighten all loose connections
- Select a location that's easily accessible

- Do not install near heat producing equipment
- Make sure the rectifier is properly grounded

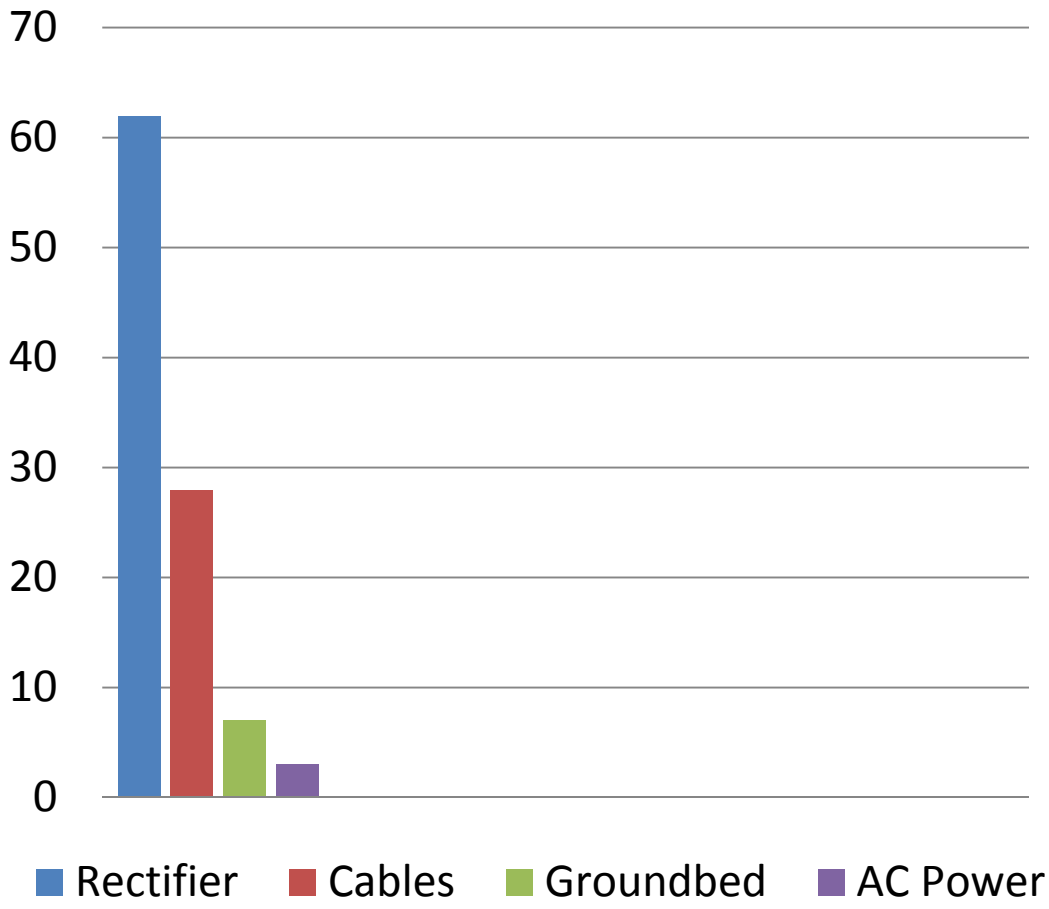
Proper Output Polarity

- **Structure = Negative**
- **Anode = Positive**



CP is a “SNAP”

Common Causes of Cathodic Protection System Failures



As with any electrical or mechanical device, rectifier downtime will occur due to unplanned failure of the equipment.

A good maintenance program will help ward off some component failures, and basic troubleshooting skills will bring the rectifier back on line.

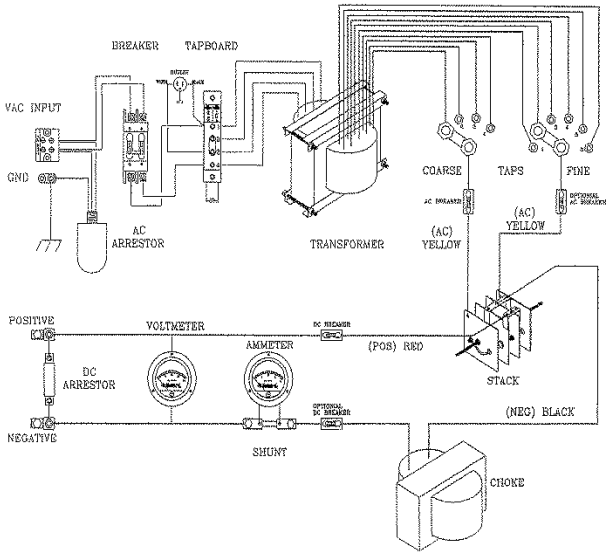
Basic Preventive Maintenance Checks And Services

- The rectifier enclosure should be maintained
- Rectifiers must be allowed to cool properly
- Rectifier enclosure must be properly grounded
- Check all connections for tightness
- All rectifier components should be kept clean
- Basic measurements should be recorded
  - AC input voltage and amperage
  - Stack AC input voltage
  - DC output voltage and amperage
  - Transformer tap settings

Rectifier Components

To best understand all components of the rectifier and their relation to one another, the best place to start is at the input

- **AC Input**
- **Input Lightning Arrestor**
- **Main Circuit Breaker**
- **Power Transformer**
- **Rectifier Stack**
- **Fuses or Secondary Breakers**
- **Meters**
- **Shunt**
- **Output Lightning Arrestor**
- **Filters**
- **Accessories**



Lightning Arrestors

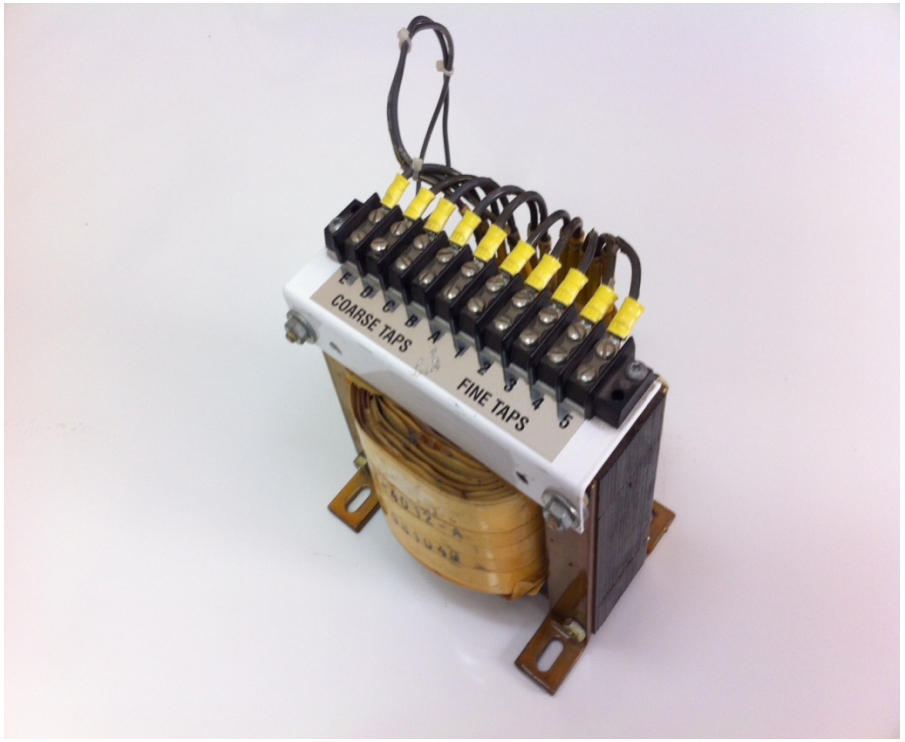
- Usually found on the input and output of the rectifier
- Protects the rectifier from extreme voltage surges
- Most configurations are a set of gapped points that an arc current can travel when a voltage surge is great enough in magnitude

Main Circuit Breaker

- Turns the incoming AC on or off
- Must be placed in each ‘HOT’ supply line
- Provides overload protection to the rectifier
- Contains either a thermal or magnetic trip element……. Or a combination of both

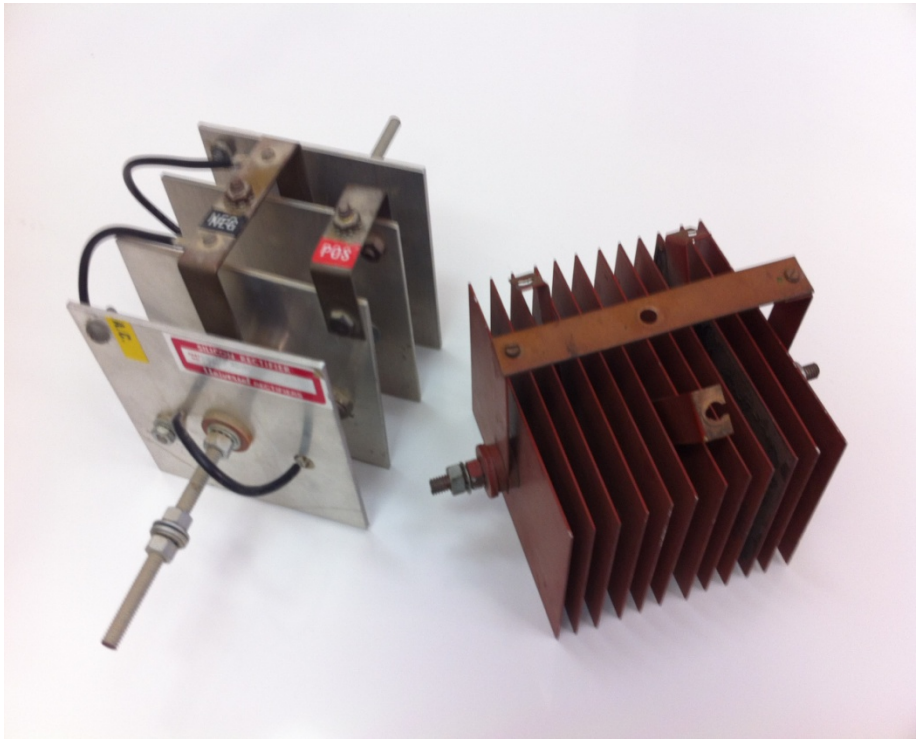
Power Transformer

- Converts the incoming AC voltage to a ‘usable’ voltage
- Primary – Input
- Secondary – Output
- The secondary allows for adjustment of the rectifier
- Most transformers used in rectifiers are step-down or ‘bucking’



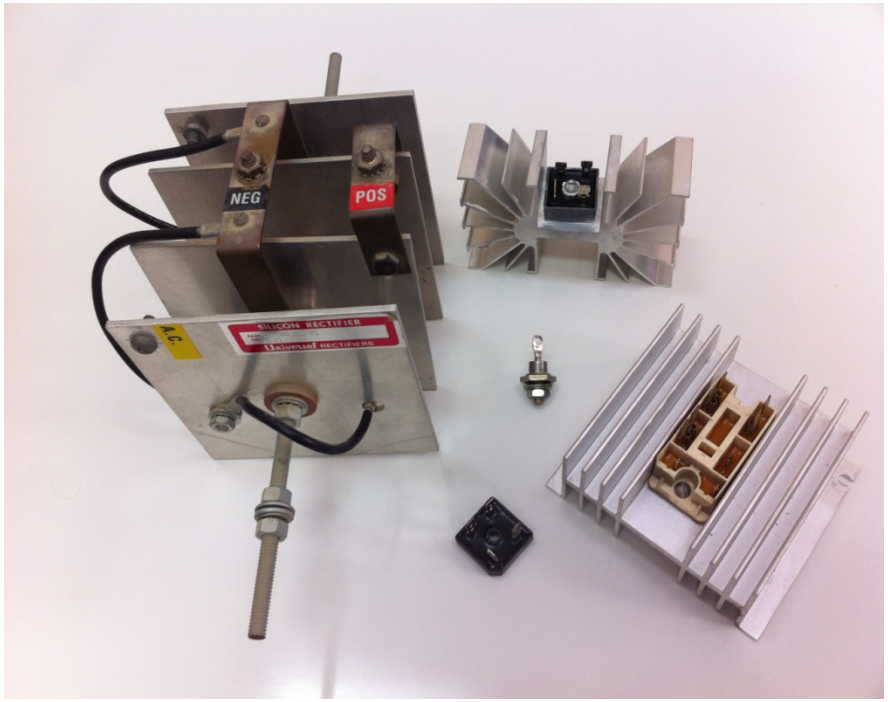
Rectifier Stack

- Converts incoming AC to DC output
- It's function is to pass current in one direction and block it in the opposite direction
- Selenium
- Silicon



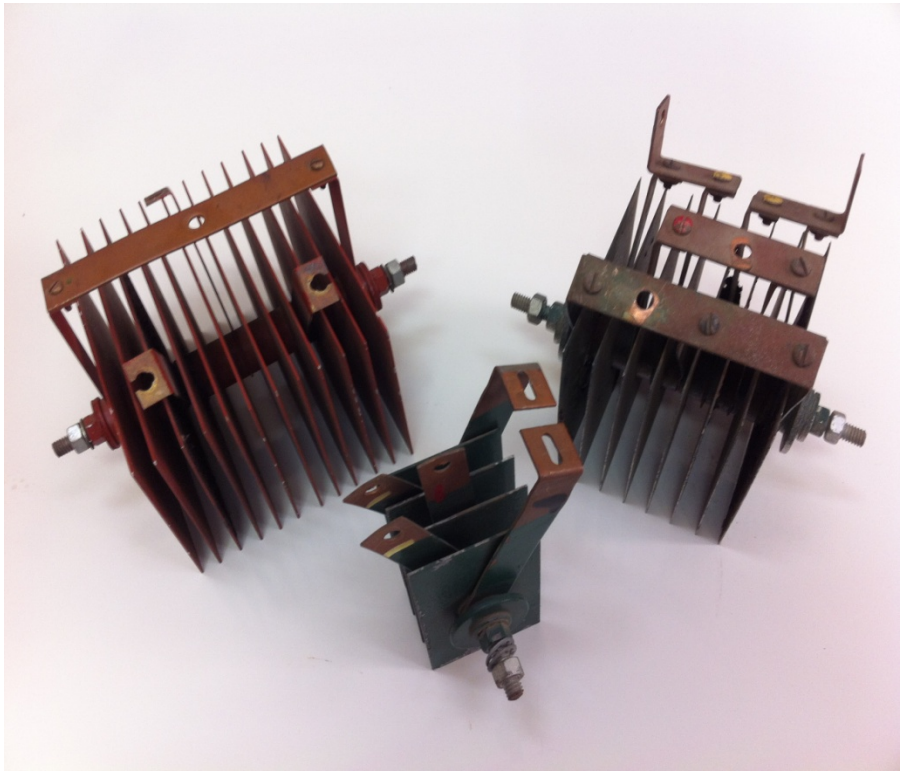
Rectifier Stack – Silicon

- Cost effective
- Very efficient
- Does not age
- Longer life
- Much higher output rating
- Easily replaced
- Must be surge protected
- Will not show signs of visible damage



Rectifier Stack – Selenium

- Can withstand Voltage surges
- Can withstand short-term overload
- Becomes less efficient with age
- Becomes less efficient with heat
- More difficult to replace
- If it looks good, it's '*probably*' good



Fuses & Secondary Breakers

- **Protects the more expensive rectifier components. Period.**

DC Output Meters

- **Used in the rectifier to indicate the amount of DC Voltage and/or current at the output**
- ***Always carry a portable volt/amp meter when servicing the rectifier, as rectifier meters have been known to give erroneous readings***

Shunts

- **Calibrated device (resistor) used in the DC Circuit for monitoring purposes.**
- **DC current can be calculated from the measured voltage drop across the shunt**

FORMULA FOR SHUNT CONVERSION

Most impressed current rectifiers are equipped with 50mV shunts

Shunt Rating	Conversion
5 Amp	mV x 0.10
8 Amp	mV x 0.16
10 Amp	mV x 0.20
12 Amp	mV x 0.24
15 Amp	mV x 0.30
20 Amp	mV x 0.40
25 Amp	mV x 0.50
30 Amp	mV x 0.60
40 Amp	mV x 0.80
50 Amp	mV x 1.00
60 Amp	mV x 1.20
75 Amp	mV x 1.50
80 Amp	mV x 1.60
100 Amp	mV x 2.00

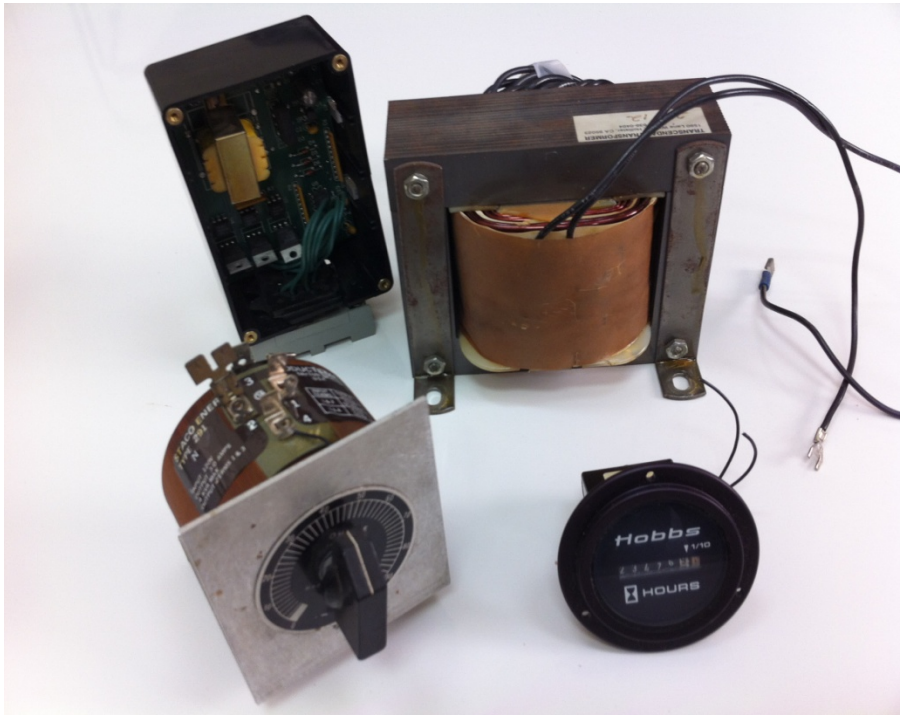
Example 1: 10 millivolts (mV) measured across a 20A / 50mV shunt
10 x 0.40 = 4 Amps

Example 2: 40 millivolts (mV) measured across a 50A / 50mV shunt
40 x 1.00 = 40 Amps

Example 3: 30 millivolts (mV) measured across a 75A / 50mV shunt
30 x 1.50 = 45 Amps

Filters & Accessories

- **All rectifier manufacturers offer various accessories to enhance their products**
  - **Filters**
  - **Lights**
  - **Alarms**
  - **AC outlets**
  - **Hour meters**
  - **Remote monitors**

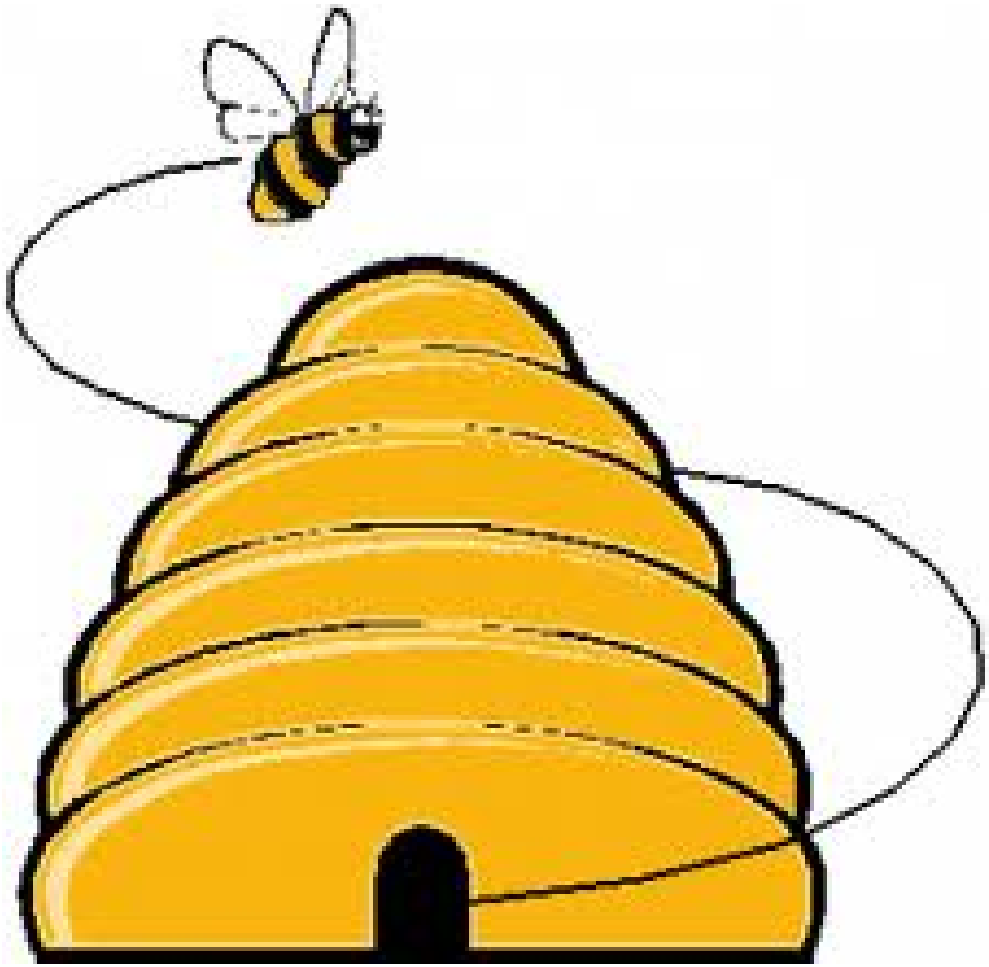


Before We Start Troubleshooting ..... A Few Precautions

Be Aware of High Voltages!

- ✓ **Backhand Rule:** Touch the rectifier enclosure with the back of your hand
- ✓ **De-energize:** If possible, disconnect the power at the source
- ✓ **One-Hand Rule:** If possible, work within the enclosure with only one hand
- ✓ **Look Away:** When energizing the rectifier, look away or cover your face
- ✓ **Insulated Hand/Foot wear:** Wear them to prevent electrocution
- ✓ **Work In Pairs:** For obvious reasons
- ✓ **Weather:** Do not attempt repairs during inclement weather
- ✓ **Jewelry:** Do not wear jewelry while working on 'live' circuits
- ✓ **Fatigue:** Do not work on energized equipment while mentally or physically fatigued
- ✓ **Maintain Constant Vigilance:** Know where you are with respect to 'live' circuits
- ✓ **Working Knowledge:** Have a general understanding of the rectifier circuit operation and basic troubleshooting skills

And Check For Nests And Other Critters!



Troubleshooting Equipment

Doesn't have to be elaborate – only functional

Proper tools will give the field technician the ability to make all repairs needed. Recommended tools and equipment might be:

- **Digital voltmeter**
- **Amp clamp**
- **Heavy shorting cables**
- **Insulated jumper cables**
- **Spare calibrated shunt**
- **Load resistor**
- **Assorted small hand tools**

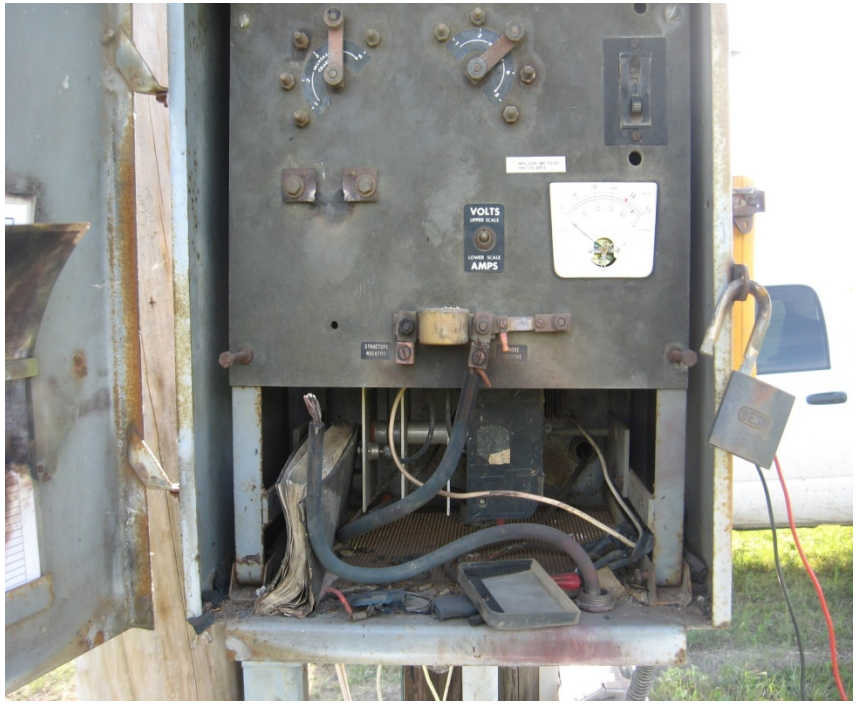
Troubleshooting

Most common rectifier problems encountered are:

- **No input – *or line* – voltage**
- **Blown fuses**
- **Faulty meters**
- **Loose or corroded terminals**
- **Open groundbed leads**
- **Lightning damage**

Most Problems Are Obvious

Some Problems Are Really Obvious



Some Problems Are Really, Really Obvious

And Some Are Tough To Find

Troubleshooting Tips

- **Many rectifier problems are obvious to the experienced technician upon physical examination. Look for loose connections, signs of arcing, strange odors or discoloration.**
- **Carry an inventory of spare parts. The most common being:**
  - **Breakers**
  - **Fuses**
  - **Diodes**
  - **Bridge rectifiers**
  - **Wire**
  - **Miscellaneous connectors**
  - **Control boards for auto-controlled rectifiers**

More Troubleshooting Tips

- **No AC line voltage:** Do not overlook the possibility that service to the rectifier may have been interrupted.
- **Defective Meters:** Never trust the rectifier meters. Always verify with a portable voltmeter known to be good.
- **Breaker tripped or blown fuse:** If the breaker trips repeatedly even with the output reduced, the cause may be a short circuit in some component ***(much more on that later).*** If the breaker trips occasionally for no obvious reason, the cause may be a temporary overload due to groundbed resistance fluctuations, line voltage surges, intermittent short circuits due to component breakdown, or the thermal breaker may be affected by sunlight or another heat source.

Even More Troubleshooting Tips

- **Open circuit in a component or connection:** Check all connections for cleanliness and soundness. Check the rectifier stack for an open-circuit condition. The diodes can be checked with an ohmmeter. ***(Again, much more on that later).***

- **Defective transformer:** If input voltage is present, check for an audible hum. If a hum is present, the primary is probably working and the secondary is open. Disconnect the AC input and isolate the transformer. Check the resistance of the windings with an ohmmeter. The secondary should have less than one ohm resistance. The primary should have one to ten ohms resistance. If either is high, the transformer should be replaced.

The Ultimate Troubleshooting Tip

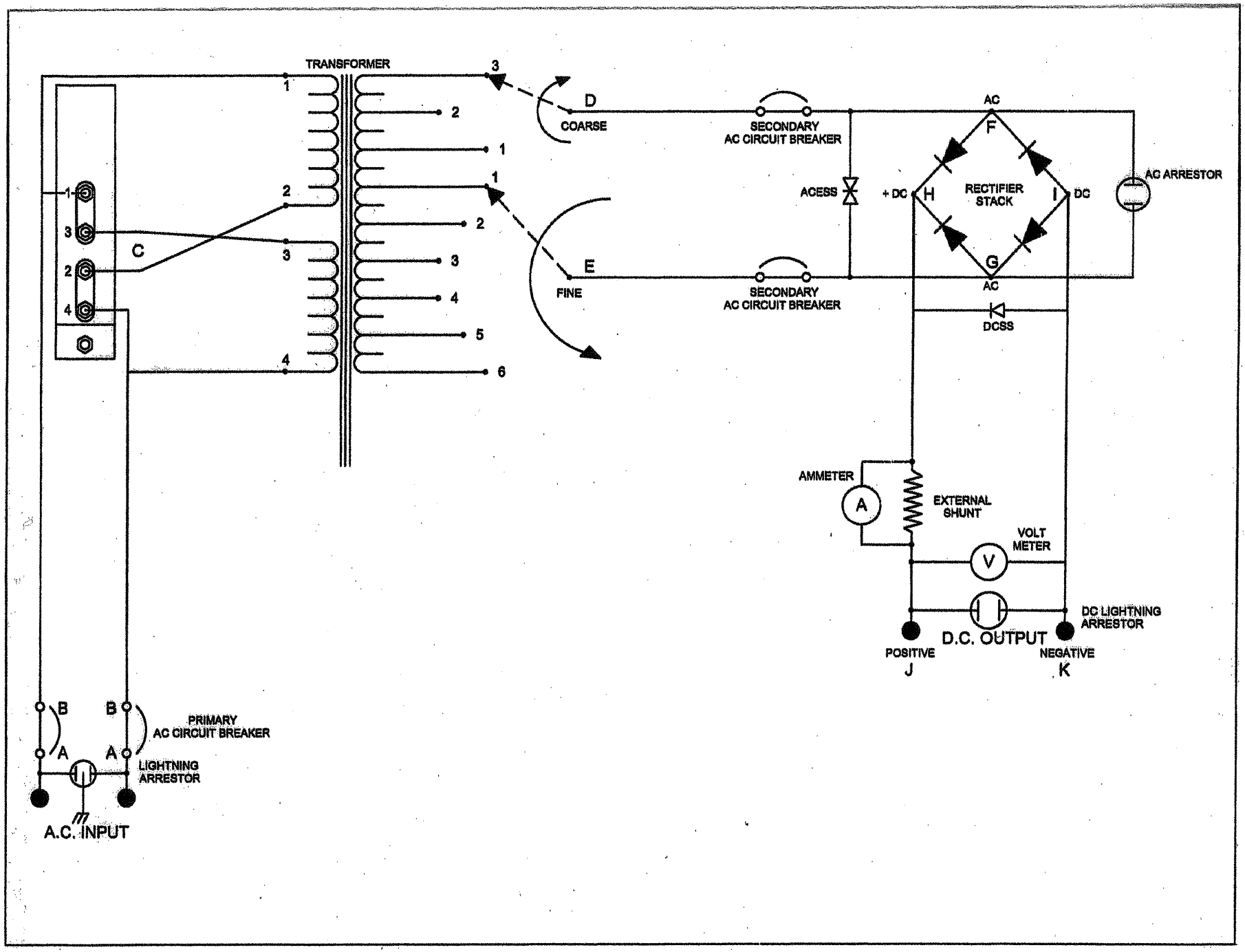
When expected DC voltage is present at the rectifier output, there is *probably* no problem with the rectifier itself – but rather, the problem is within the external (groundbed) circuit.

-In Other Words-

DC Output Voltage = Good Rectifier

Troubleshooting Procedure
No Output

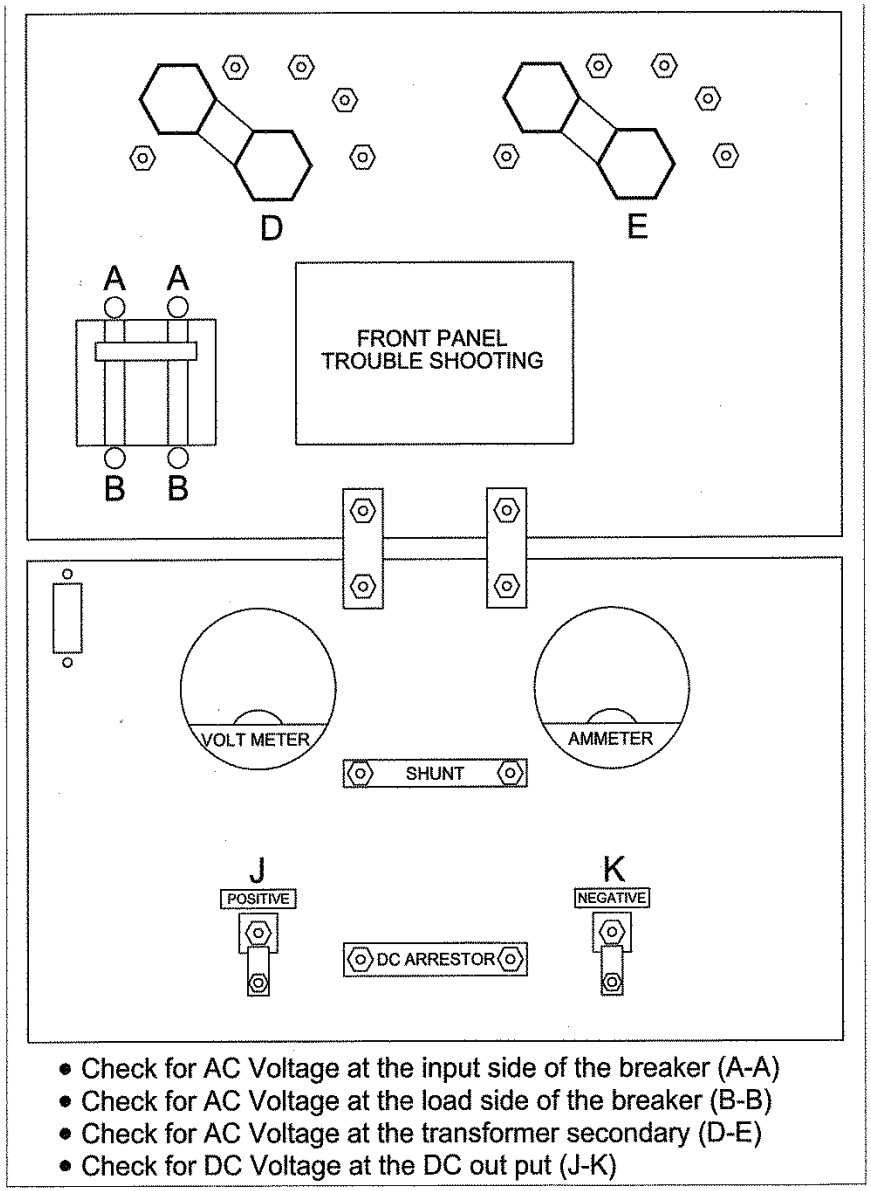
- Check the input voltage. Us the AC voltage setting of the voltmeter to measure across the line side of the circuit breaker **(A-A)**.
- Check across the load side of the circuit breaker **(B-B).** The measured voltage should be the same as measured on the line side.
- Check the input voltage change taps for loose or dirty connections. Verify that the tap change bar is in the proper position **(C).**
- Check the transformer secondary with your AC voltmeter **(D-E).**
- Measure the AC voltage supplied to the rectifier stack **(F-G).** This voltage should be the same as was measured at the transformer secondary.
- Measure the DC voltage at the rectifier stack output **(H-I).** The stack can be isolated from the rest of the DC circuit by removing either lead at H or I.
- Check the DC voltage at the rectifier output **(J-K).** If DC voltage is present but is much less than expected, the stack will have to be examined. If the DC voltage is about half of that expected, turn the rectifier off and feel the individual plates of the stack. If the temperature of the individual plates is not uniform, the stack has an open and is half-waving. Defective diodes and/or associated wiring will have to be replaced.
- If DC voltage is present at the stack but not at the output, check for loose connections or open leads between the stack and the output. Don’t forget about the DC fuse.


TRANSFORMER
1
2
3
4
5
6
D
COARSE
E
FINE
C
SECONDARY
AC CIRCUIT BREAKER
SECONDARY
AC CIRCUIT BREAKER
ACESS
AC
F
+ DC
H
RECTIFIER
STACK
I
DC
G
AC
AC ARRESTOR
DCSS
AMMETER
A
EXTERNAL
SHUNT
VOLT
METER
V
DC LIGHTNING
ARRESTOR
POSITIVE
J
D.C. OUTPUT
NEGATIVE
K
B
B
PRIMARY
AC CIRCUIT BREAKER
A
A
LIGHTNING
ARRESTOR
A.C. INPUT

Troubleshooting Procedure
Main Breaker Trips

- Remove the lightning arrestors and try again.
- If the breaker continues to trip, isolate the breaker from the rectifier by removing either lead from the load side of the main breaker **(B-B).** If the breaker trips, the breaker is defective. If it holds, the breaker is good. Reconnect and try again.
- If the breaker continues to trip, isolate the transformer from the DC circuit by removing either secondary tap link bars **(D or E).** Try again.
- If the breaker continues to trip, the transformer is shorted and will probably have to be replaced or adjusted. If the breaker does not trip, the short circuit is in the DC circuit.
- Remove either DC lead from the rectifier stack **(H or I).** If the breaker trips, the rectifier stack will have to be replaced or repaired. If the breaker does not trip, the short is still downstream – either in a rectifier output accessory, or the groundbed circuit.

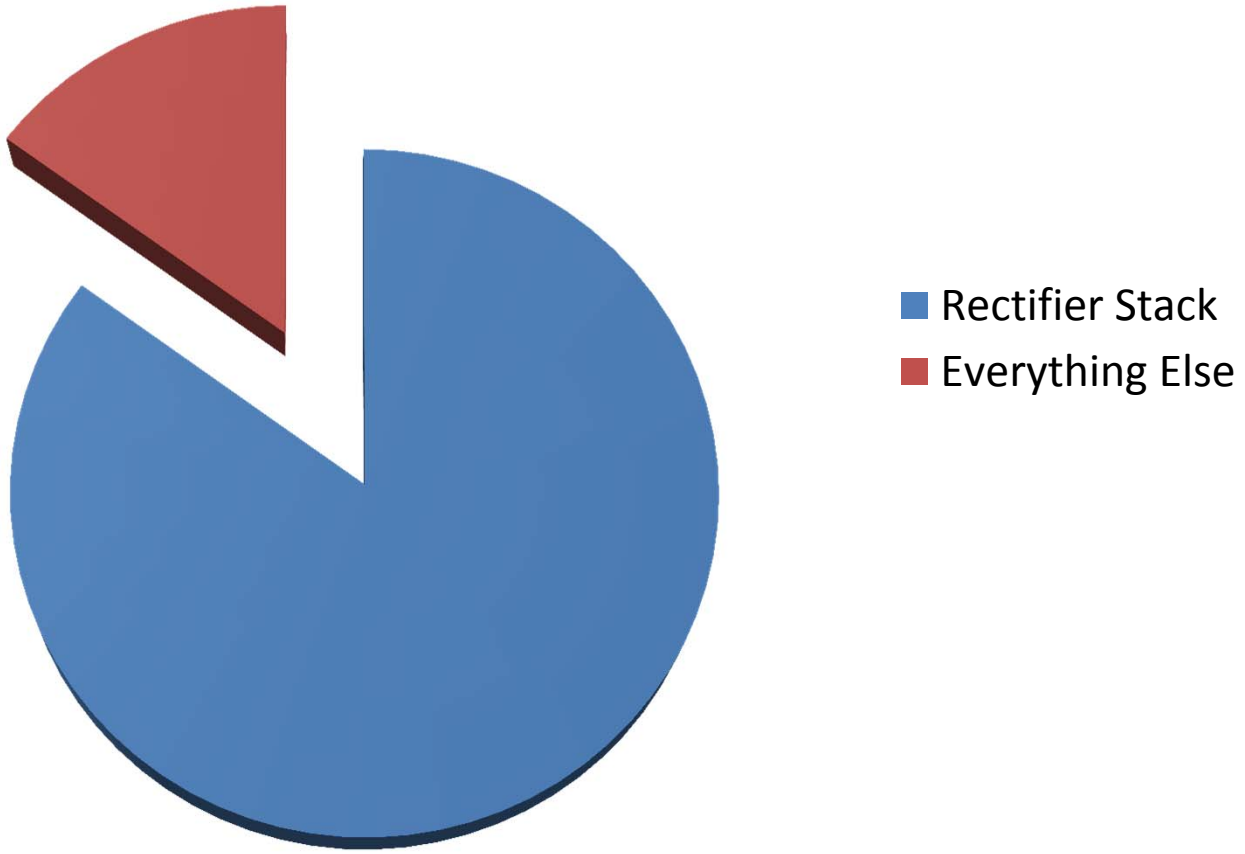
Dead-Front Rectifier Troubleshooting



- Check for AC Voltage at the input side of the breaker (A-A)
- Check for AC Voltage at the load side of the breaker (B-B)
- Check for AC Voltage at the transformer secondary (D-E)
- Check for DC Voltage at the DC out put (J-K)

Most Common Cause Of Rectifier Failure

Approximately 80% Of All Rectifier Failures Occur At The Rectifier Stack



HOW TO CHECK THE RECTIFIER STACK – IN CIRCUIT

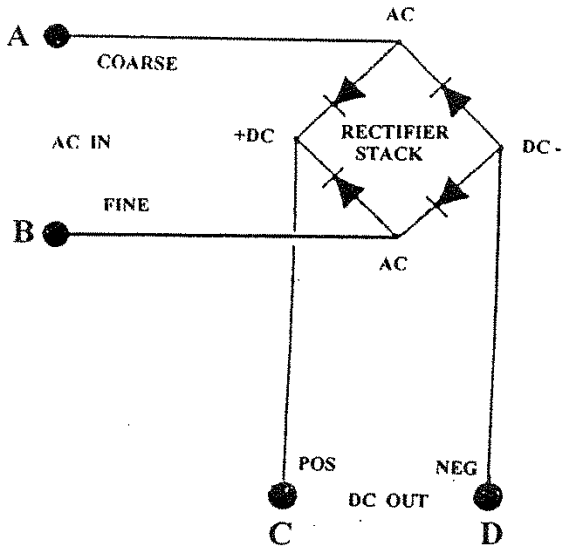
- Remove one of the tap change link bars ***AND*** either the anode (+) or structure (-) output connection. *This will isolate the stack from the transformer and the groundbed.*
- Set the multimeter to the Ohm or Diode check position

1. Place the red lead of the multimeter on the Coarse tap (**A**) and the black lead on the Anode or Positive lug (**C**). A low reading – *but not zero* – should be indicated on the meter. If the reading is zero or very high (OL), the diode has failed. Now the diode must be checked in the reverse direction. Place the red lead of the multimeter on the Anode or Positive lug (**C**). Place the black lead on the Coarse tap (**A**). The meter should indicate an "open circuit" and may read "OL". If the reading is zero, the diode has failed.

   So far, this procedure has checked one of the four diodes that make up the stack

2. Place the red lead of the multimeter on the Fine tap (**B**) and the black lead on the Anode or Positive lug (**C**). Again, a low reading – *but not zero* – should be indicated on the meter. If the reading is zero or very high (OL), the diode has failed. Again, check this diode in the reverse direction. Red lead to the Positive lug (**C**). Black lead to the Fine tap (**B**). An "open circuit" or "OL" should be read if the diode is good.

   Both diodes that make up the positive side of the stack have been checked. The following steps will check the two diodes that make up the negative side



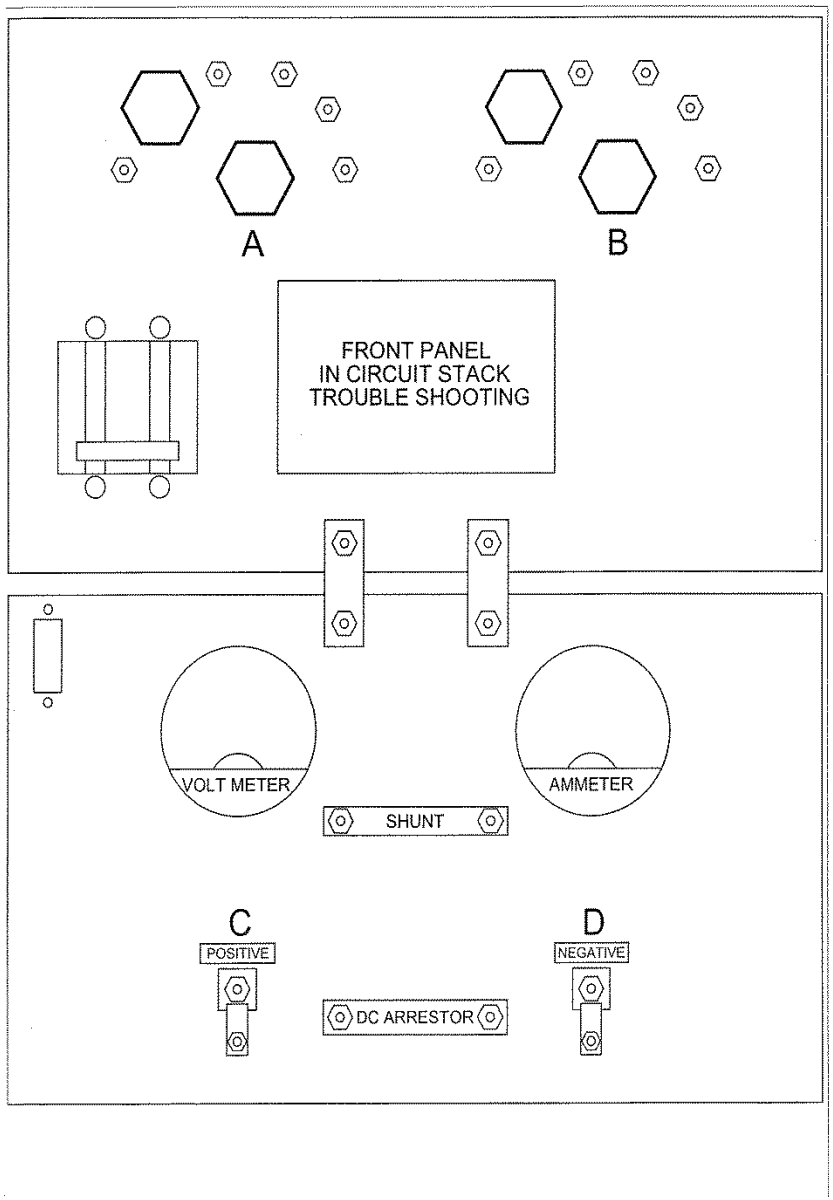
3. Place the multimeter's black lead on the Coarse tap (**A**) and the red lead on the Structure or Negative lug (**D**). Again, a low reading – *but not zero* – should be indicated if the diode is good. The same will be true if the black lead is moved to the Fine tap (**B**).

   Both diodes that make up the negative side of the stack have just been checked in the forward direction. The following step will check the same diodes in the reverse direction

4. With the multimeter red lead on the Coarse tap (**A**) and black lead on the Structure or Negative lug (**D**), the meter should essentially read an "open circuit" (OL) if the diode is good. The same will be true if the red lead is moved to the fine tap (**B**).

   If any readings other than those given above are observed, there is a bad diode in the rectifier stack and it will need to be replaced before the rectifier power supply will work

Dead Front Stack Check



So…… To Summarize

- ✓ Proper Rectifier Selection
- ✓ Know Your Troubleshooting Procedures
- ✓ Know your Troubleshooting Equipment
- ✓ Maintain Constant Vigilance
- ✓ Have A Plan
- ✓ Work Your Plan
- ✓ Good Luck!

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