Industrial Tubes

by

NATIONAL®

OPERATION AND MAINTENANCE HINTS FOR IGNITRONS, THYRATRONS AND RECTIFIERS

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PREFACE

The discussions to follow are offered as an aid to those responsible for the maintenance of industrial electronic equipment and the servicing of this equipment to obtain maximum reliability and life. Since the electronic tube is the heart of this equipment, the discussions are directed toward establishing environmental conditions for the tube which will enable it to operate properly and give maximum service. Electronic tubes are long-lived devices when properly treated.

The authors have attempted to simplify this material so that it is readily usable with a minimum of instrumentation. It is not the intent that information herein should be used in lieu of instructions furnished with equipment by the manufacturer of such equipment. Any procedures herein described should not be considered as superseding or contradicting procedures prescribed by the manufacturer of such equipment.

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ILLUSTRATIONS

Part I
IGNITRONS

1-1. IGNITRON THEORY.

a. DEFINITION AND DESCRIPTION. The ignitron is a gas-discharge electronic tube with a mercury pool cathode and an ignitor starting electrode. There are five basic parts in an ignitron, namely: The cathode, anode, ignitor, terminals, and envelope. A typical ignitron is illustrated in figure 1. The basic elements and their properties are discussed in subparagraphs b through f following.

b. ELECTRON FLOW.

(1) The flow of electrons in a wire can be compared to the flow of water through a pipe. The current flowing through a wire consists of millions of electrons moving in a group, just as millions of molecules flowing through a pipe produce the water flow.

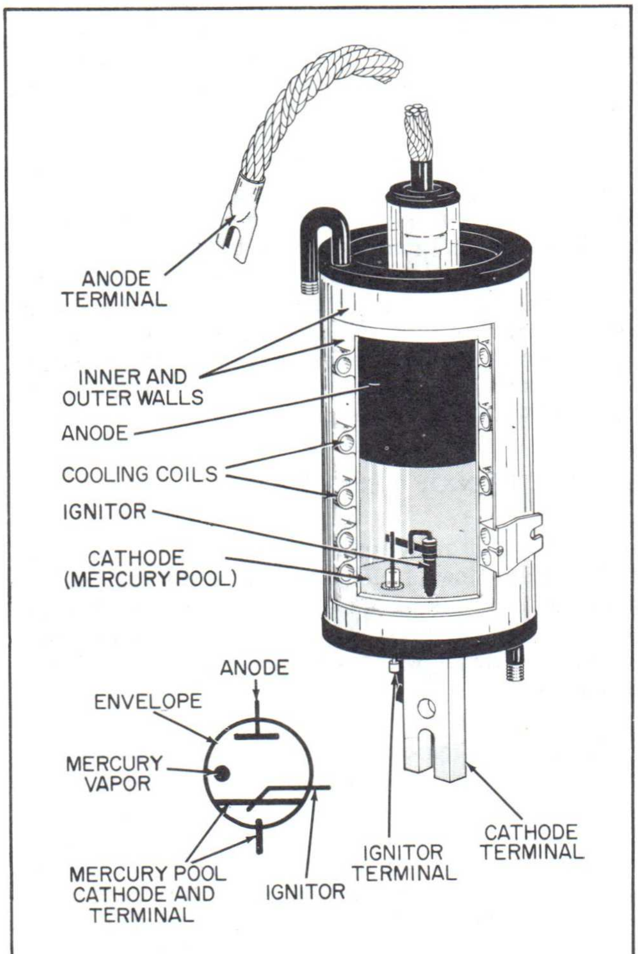


Figure 1. Ignitron Elements and Graphic Representation

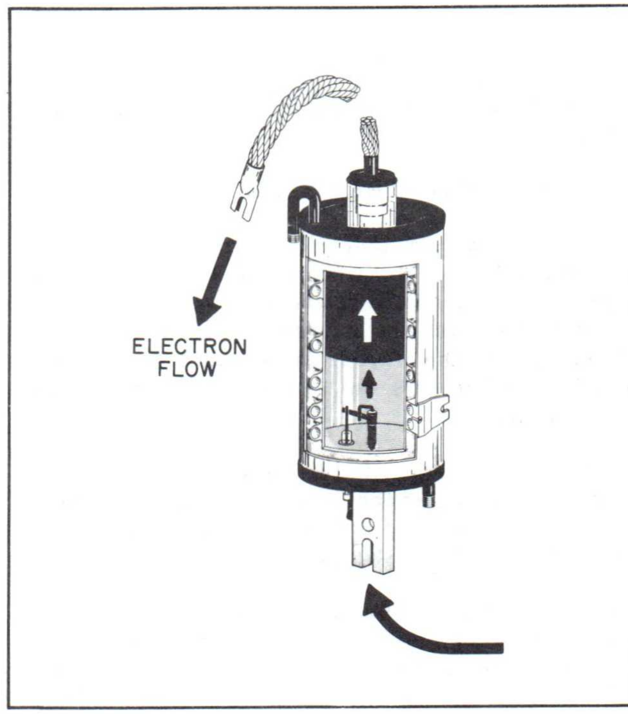


Figure 2. Electron Flow Through an Ignitron

(2) As long as electrons in a wire fail to flow in the desired direction they produce no useful result, similar to the immobility of water in a pipe where there is no flow. An electric generator or battery is comparable to a water pump, and a water valve is comparable to a switch, variable resistance, or an electron tube insofar as the control of electron current is concerned.

(3) The requirements of industrial electronic equipment require that precise control of the flow of electrons be provided. High speed relays could be used to control the starting and stopping of electron flow, however, even the fastest relays are slow compared to the switching action of ignitrons. An ignitron can be turned on and off with precision measured to a few microseconds. In addition to the precise and rapid switching action, the further usefulness of ignitrons lies in the ability to control the magnitude of the current flowing to the load.

Thus, an ignitron not only functions as a switch, but also as a precisely controlled variable resistor and timing device.

(4) The accepted theory of current flow states that electric current flows from the positive terminal. Experiments and developments within recent years have proven that electrons flow toward a point of more positive potential. This current flow is referred to as an electron current, and is the current flow described and illustrated in this book.

(5) The following paragraphs explain how this flow of electrons in an ignitron is accomplished and how the precise control of this electron flow is accomplished.

c. FUNCTION OF THE CATHODE.

(1) Visualize an electrical circuit in which a switch is used to control the flow of electrons. When the switch is closed, electrons flow; when the switch is opened, electron flow ceases. In electronic control equipment, the switch is replaced by an electron tube, and in this discussion the electron tube is an ignitron.

(2) Since the ignitron tube is connected into the electrical circuit and the circuit continuity is broken, electrons must flow thru the ignitron. The electron flow is from the cathode to the anode.

(3) Electrons cannot pass through the gap between the cathode and anode unless some additional influence or element is introduced which will initiate the flow of electrons.

(4) In an ignitron tube, the cathode consists of a pool of mercury, sometimes five or six inches in diameter. This pool of mercury is the source of electrons, which in the case of larger ignitrons, will supply approximately 10^{25} ("1" followed by 25 zeros) electrons per second when the ignitron is firing.

(5) Unlike most other electronic tubes, the cathode of an ignitron is a pool of mercury and is not heated to release electrons.

(6) Instead of a hot cathode a starting electrode, called an ignitor, is used to strike an arc at the surface of the mercury pool, thereby releasing electrons from the cathode. The function of the ignitor will be described in detail later in the discussion. This electric arc liberates an infinite number of electrons which will flow toward the anode, providing it is positive with respect to the cathode.

d. FUNCTION OF THE ANODE.

(1) The anode is the element within the ignitron which attracts the free electrons liberated from the cathode. This attraction exists just as long as the anode is positive with respect to the cathode.

(2) When an ignitron is connected into an alternating current circuit the anode is positive for one-half cycle, and negative for the next half cycle. When the anode is negative, electron flow stops since the anode is incapable of emitting electrons. This is a principle characteristic of an ignitron, and of other electron tubes also. The ignitron acts like a rectifier, except that the time of actual firing during the positive half cycle can be controlled with precise accuracy.

(3) The anode of an ignitron is made of graphite for three principle reasons: Graphite will not emit electrons under the normal operating conditions; graphite has low electrical resistance, actually decreasing with an increase of temperature; and the dull black surface of graphite is an excellent heat radiator. The last item is very important since the dissipation of the internally-generated heat in an ignitron is essential.

(4) Due to the presence of mercury in an ignitron, and consequently mercury vapor, the space between the cathode and anode is filled with millions of mercury vapor molecules. The mercury vapor molecules, which are much larger than the electrons, are bombarded by the electrons flowing toward the anode. This bombardment knocks electrons out of the mercury vapor molecules, thereby producing positive ions.

(5) In addition to the electrons emitted from the mercury pool cathode, the liberated mercury electrons also flow to the anode, thus increasing the total number of electrons attracted by the anode. The ions remain in the tube for a relatively long time and have the affect of neutralizing most of the space charge within the tube. This ionization of the mercury vapor molecules is the reason for the greater current carrying capacity of gas filled tubes as compared with high-vacuum tubes.

e. FUNCTION OF THE IGNITOR.

(1) The ignitor element in the ignitron is used to trigger the flow of electrons from the cathode to the anode by striking an arc at the mercury pool surface. This arc then transfers to the anode and will sustain itself without further assistance from the ignitor.

(2) Once the ignitor has liberated electrons from the cathode, in the manner explained previously, there is no further requirement for its functioning until the next positive cycle occurs at the anode. This being the case, a pulse of positive voltage from a thyratron trigger circuit or equivalent device is used to fire the ignitor. Once electron flow from cathode to anode has been established, the ignitor relinquishes control and only a removal or phase reversal of the anode potential will stop the current flow.

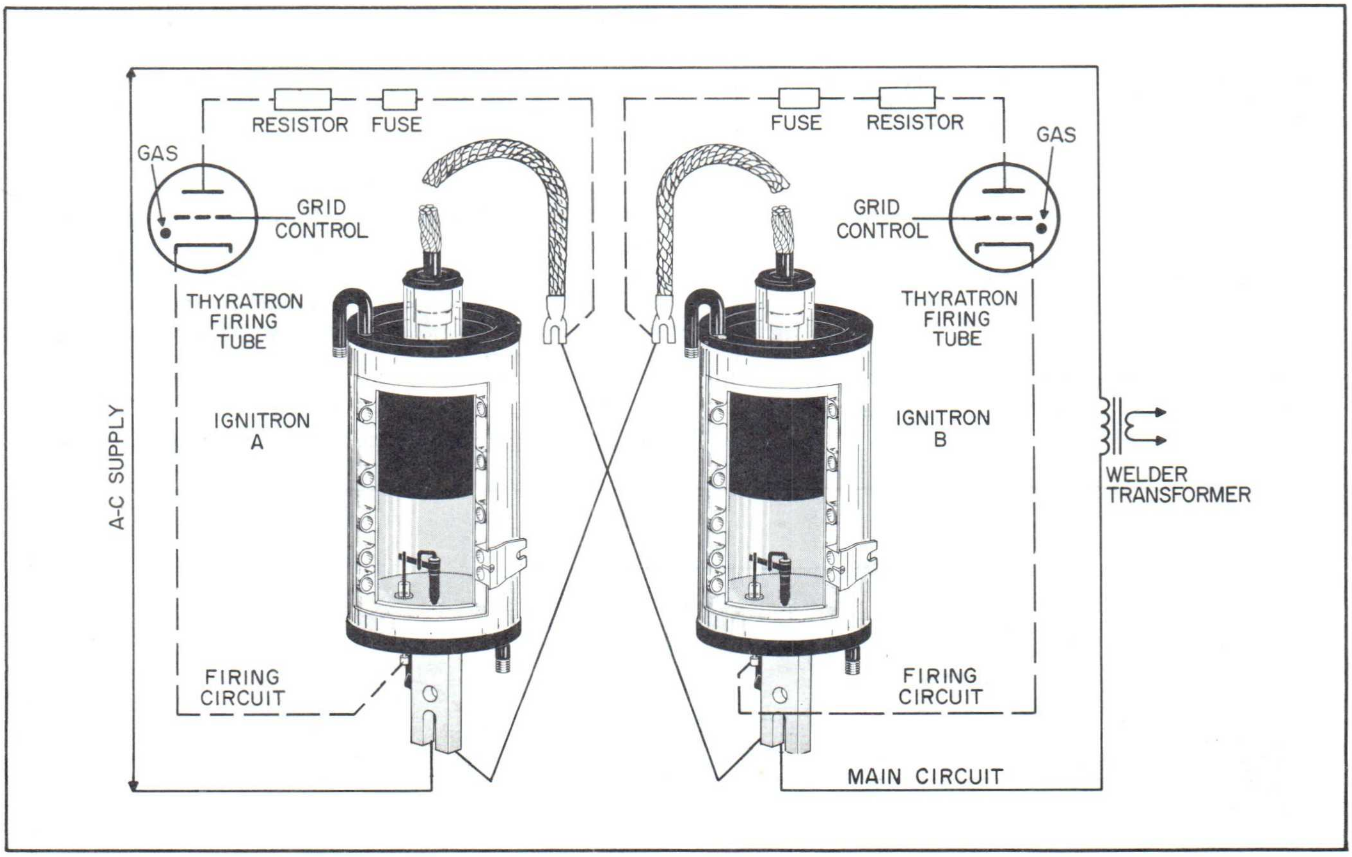


Figure 3. Functional Circuit of an Ignitron Welder

f. FUNCTION OF THE ENVELOPE.

(1) The primary function of the envelope of ignitron tubes is to maintain a vacuum tight enclosure around the operating elements.

(2) In addition to the vacuum tight enclosure, a cooling means is incorporated in the envelope to dissipate the heat developed in the tube.

(3) The most common and efficient method of cooling is accomplished by circulating water thru copper cooling coils brazed to the inner envelope, or by making a double-walled envelope and circulating water thru the double-wall enclosure.

(4) Ignitron tubes using convection cooling or forced air cooling can be designed, however, the use of a liquid coolant provides the highest degree of efficiency, control and longevity.

g. IGNITRON FUNCTIONAL CIRCUIT.

(1) Two circuits are used in an ignitron tube welding control, the main or cathode to anode circuit, and the firing or ignitor circuit. Figure 3 shows how these circuits are used to incorporate an ignitron tube into a welding equipment control circuit.

(2) In power rectification, a third circuit is used called the holding anode circuit. A small auxiliary anode is used to maintain a sufficiently high degree of ionization to maintain the mercury arc even at fractional loads.

h. IGNITRON THEORY ANALYSIS.

(1) As stated previously, the ignitron has five basic parts - cathode, anode, envelope, terminals, and a starting electrode called an ignitor.

(2) The difference in the operation of ignitron tubes as compared with other tubes is in the method of liberating electrons from the cathode and thereby initiating current flow.

(3) The cathode of the ignitron is a pool of mercury, instead of the conventional coated metal found in most other electronic tubes.

(4) The electrons are liberated from the mercury pool by forming or striking an arc between the ignitor and the mercury. This differs from most electronic tubes in which the electrons are liberated by heating the coated-metal cathode to a sufficiently high temperature to free the electrons.

(5) As shown in figure 4, the tip of the ignitor is immersed in a mercury pool. Due to the very

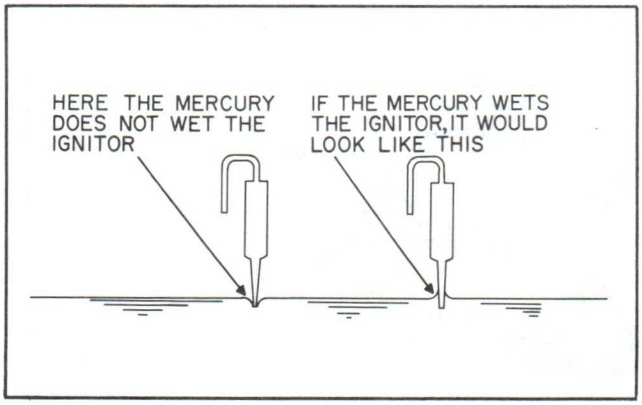


Figure 4. Ignitor in the Mercury Pool

strong surface tension of mercury, a slight pulling-away occurs where the mercury touches the ignitor. This is indicated by the downward dip (called a meniscus) of the mercury at this point. If the mercury "wets" the ignitor, an upward flow (like a fillet) would result.

(6) When a peak current of 10 to 40 amperes is passed through the ignitor-cathode circuit, a high potential (voltage) difference is established between the ignitor and mercury pool. When this potential difference is sufficient to strike an arc, electrons are liberated from the mercury and a cathode spot or arc is formed.

(7) Voltage required to force current through the ignitor prior to firing is on the order of 100-200

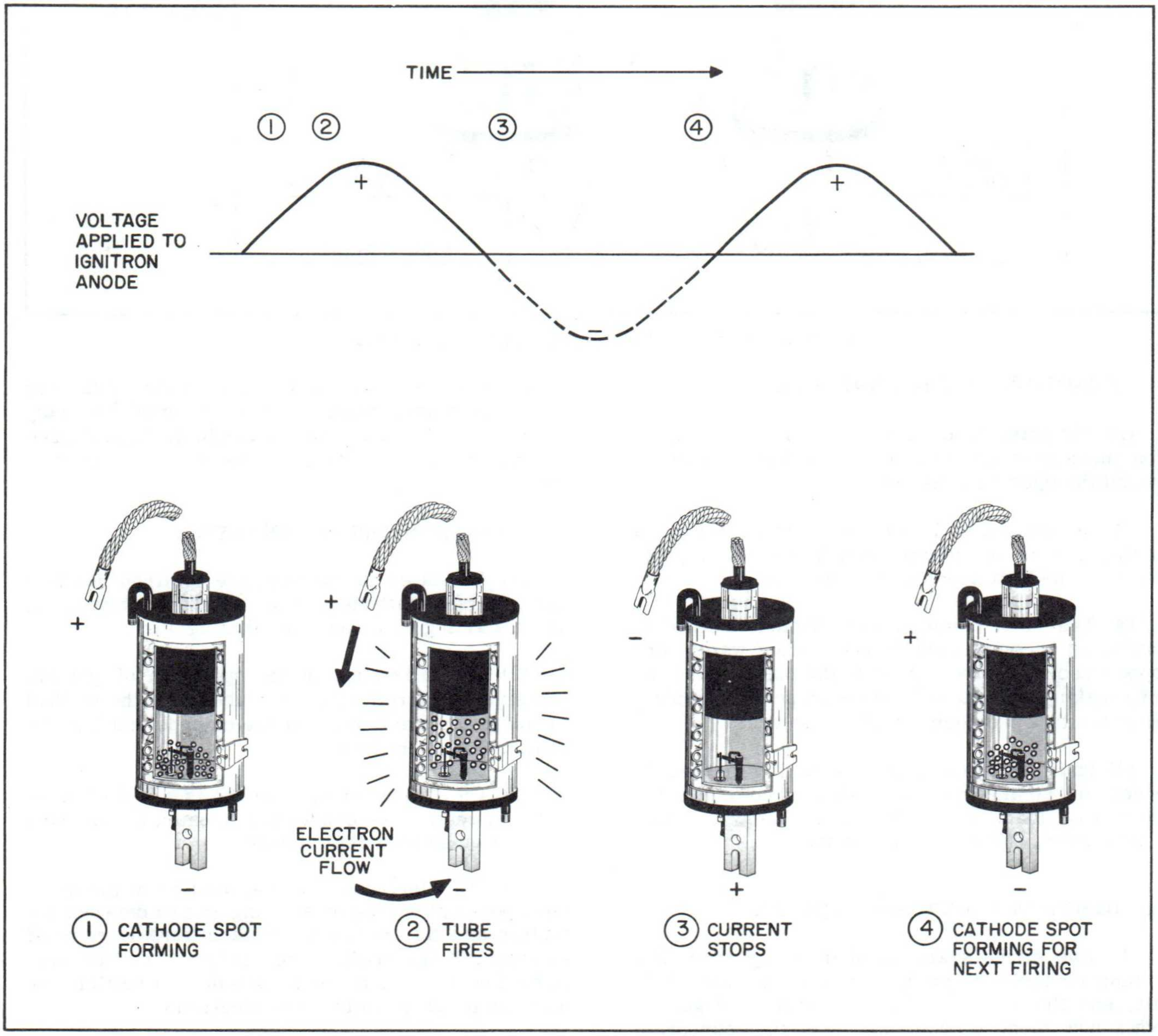


Figure 5. Ignitron Rectification

volts. As soon as the ignitor fires, this voltage drops to about 10 volts.

(8) As the ignitor current increases beyond a critical point, the potential gradient causes tiny sparks to form at the meniscus. These sparks are the beginning of a cathode spot which spreads over the surface of the mercury until a sufficient number exist to supply the current demand. Literally billions of electrons are released from each cathode spot since it takes 6,182 times 10^{18} electrons to conduct one ampere for one second.

(9) During the cycle when the anode becomes positive it attracts the electrons given off by the mercury-pool cathode, thus conducting current through the tube. Obviously, when the anode becomes negative or opened the current flow stops.

(10) It is necessary to re-ignite the cathode spot in order that electrons will be available when the anode is positive again. The ignitron circuit is designed so that the ignitor current flows only for the short period of time necessary to start the electron flow. At the end of this time, and until the next cycle, the ignitor current is essentially zero.

(11) The mercury-pool cathode is repeatedly renewed by condensation of the mercury vapor, therefore it is practically indestructible.

(12) The cathode-to-anode current can be turned off only by reducing the anode potential below the ionization potential of mercury vapor, or by allowing the anode to swing negative, as during the negative half cycle. Once the ignitron fires, the ignitor circuit loses all control of the cathode-to-anode current until the anode current drops to zero.

i. RECTIFICATION WITH AN IGNITRON.

(1) In 60-cycle alternating current, the current changes direction 120 times each second (twice each cycle). A diagram for three half-cycles of alternating current is shown in figure 5. Total time required is 3/120 second.

(2) Electrons flow from the cathode to the anode only while the anode is positive. At the point in the diagram where the broken line begins, the anode has just reached zero potential and is about to become negative, therefore the flow of current stops. The ignitor ceases to function once the current has started, and current will not flow through the tube during the next positive half cycle until the ignitor produces another cathode spot.

(3) In ignitron tubes used for rectifier service, the ignitor may be triggered to start the flow of current again at any time after the anode becomes positive again. The ignitor timing may be delayed thereby controlling the average current conducted by the tube.

j. CURRENT CONTROL WITH AN IGNITRON.

(1) An ignitron tube with the aid of thyratrons and other electronic devices, can provide precision control over the current flowing through a circuit. This type of control is essential where ignitrons are used to feed current into the primary of a welding transformer. (See circuit in figure 3).

(2) In ordinary rectifier service, the ignitor starts current flow at the beginning of each positive half-cycle. The entire cycle of operation repeats continuously thus providing an output of pulsating direct current.

(3) For resistance welding, direct current is unimportant since resistance welding is usually done with alternating current. By connecting two ignitron tubes in inverse parallel (the anode of one tube connected to the cathode of the other, figure 3) each tube will conduct on opposite half-cycles and the output of both tubes together is still alternating current.

(4) Ignitron tubes make it possible to obtain precise control over the average amount of current flowing through a circuit. This is done by controlling the exact point at which the ignitor is fired. The switching accuracy of ignitrons is extremely good and this feature together with no relay contact wear make ignitrons extremely valuable in industrial control equipment.

(5) In most welder circuits, the ignitron tubes are required to conduct in a more complex sequence. The conduction time of the ignitron tubes are illustrated in figure 6. There are actually four phases of operation involved, "squeeze" time, "weld" time, "hold" time, and "off" time. The ignitrons fire only during the "weld" time, each ignitron sharing the load as shown in figure 6. The larger the shaded areas, the larger the average current output will be.

(6) In the same welder circuit, another job might require less heat, therefore less current. If the job requires less current, the ignitrons are controlled to pass current during a smaller fraction of each half-cycle.

(7) The timing diagram (figure 6) shows two complete cycles allocated to "weld" time. This "weld" time, as well as the "squeeze", "hold", and "off" times are usually adjustable in most spot welders.

(8) Therefore, it is obvious that two items control the average current output of the ignitron, first of all, the number of cycles allocated to the "weld" time, and the proportion of each "weld" cycle allocated for firing.

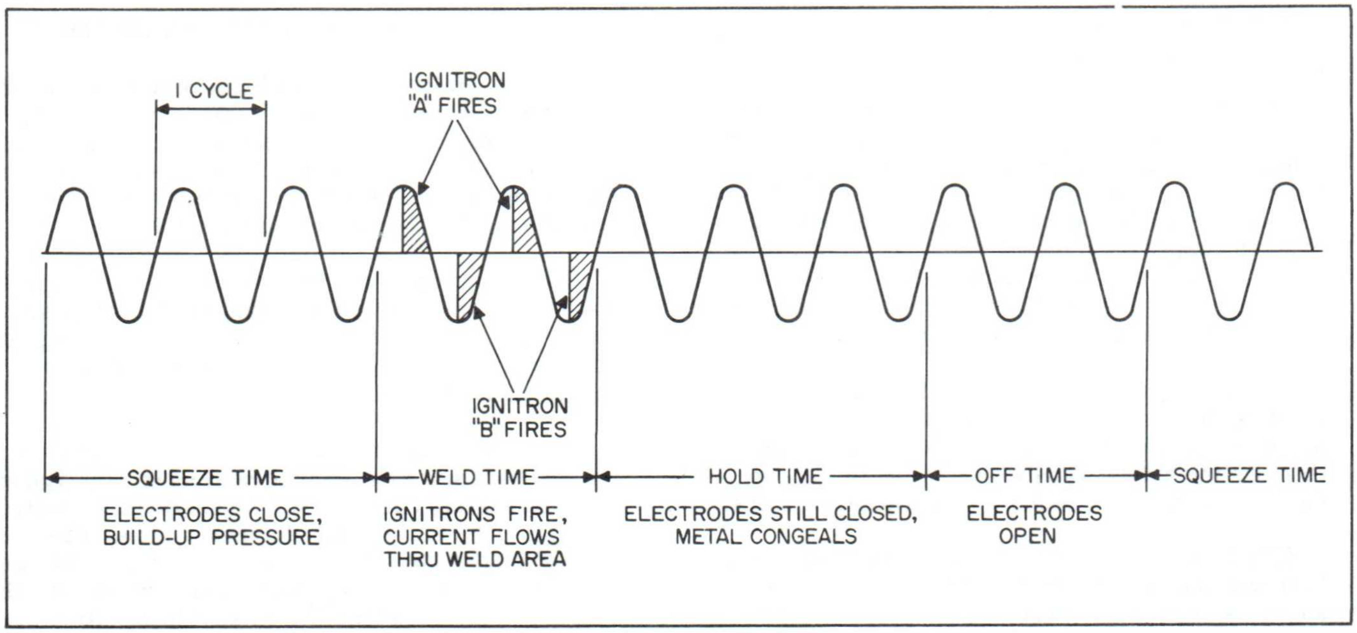


Figure 6. Ignitron Current Control

1-2. OPERATING SUGGESTIONS.

a. GENERAL. There are three basic conditions which usually result in complete ignitron failure or sporadic operation. These are:

(1) Exceeding maximum tube ratings.

(2) Insufficient flow of cooling water.

(3) Ignitor firing tube malfunction.

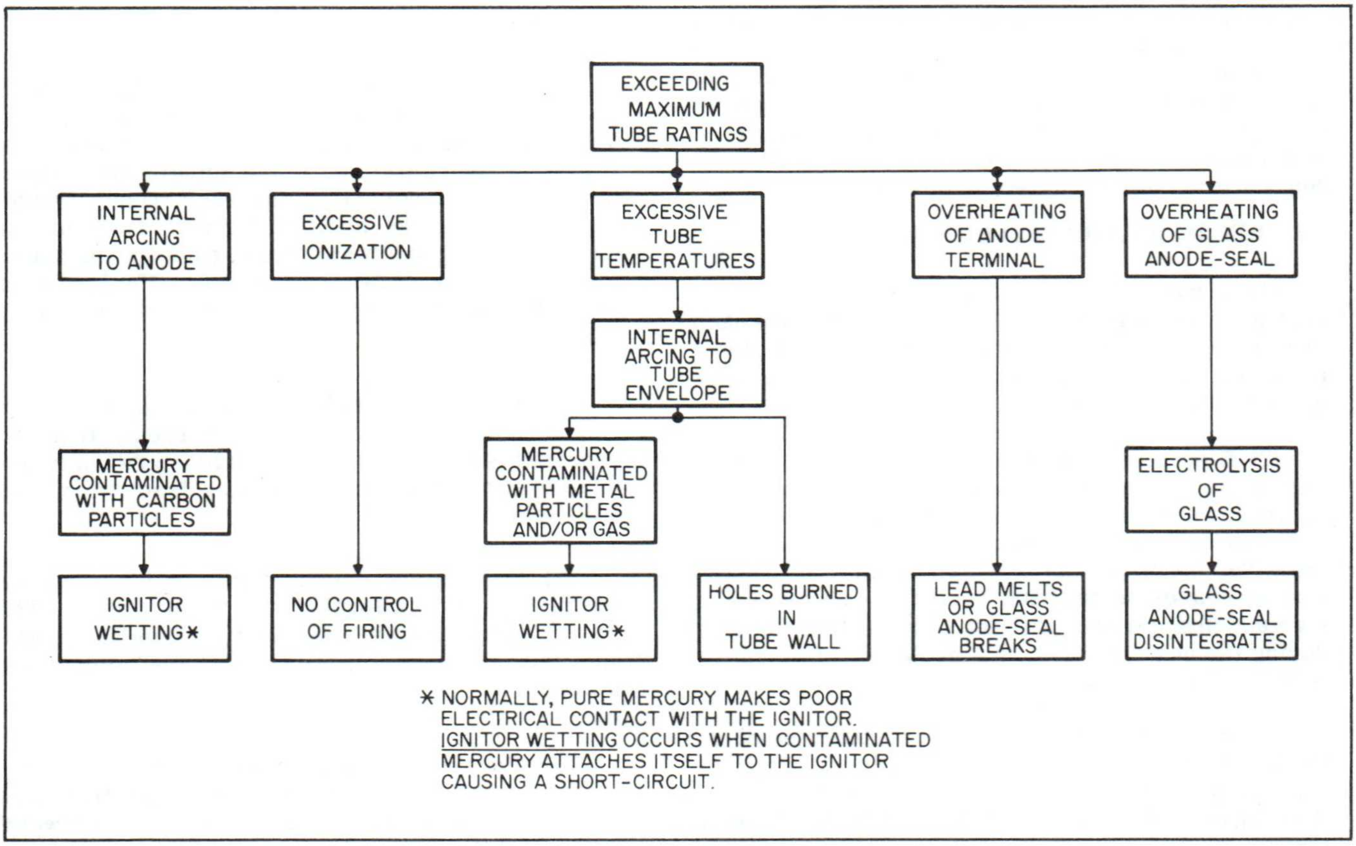


Figure 7. Effects of Exceeding Maximum Tube Ratings

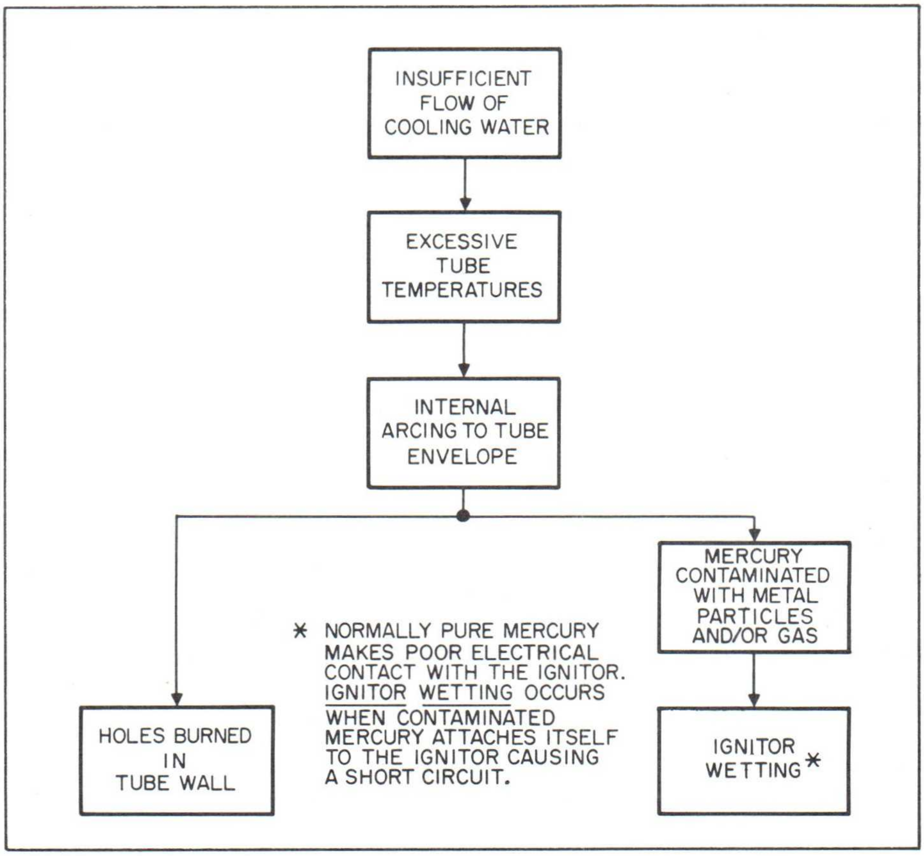


Figure 8. Effects of Insufficient Flow of Cooling Water

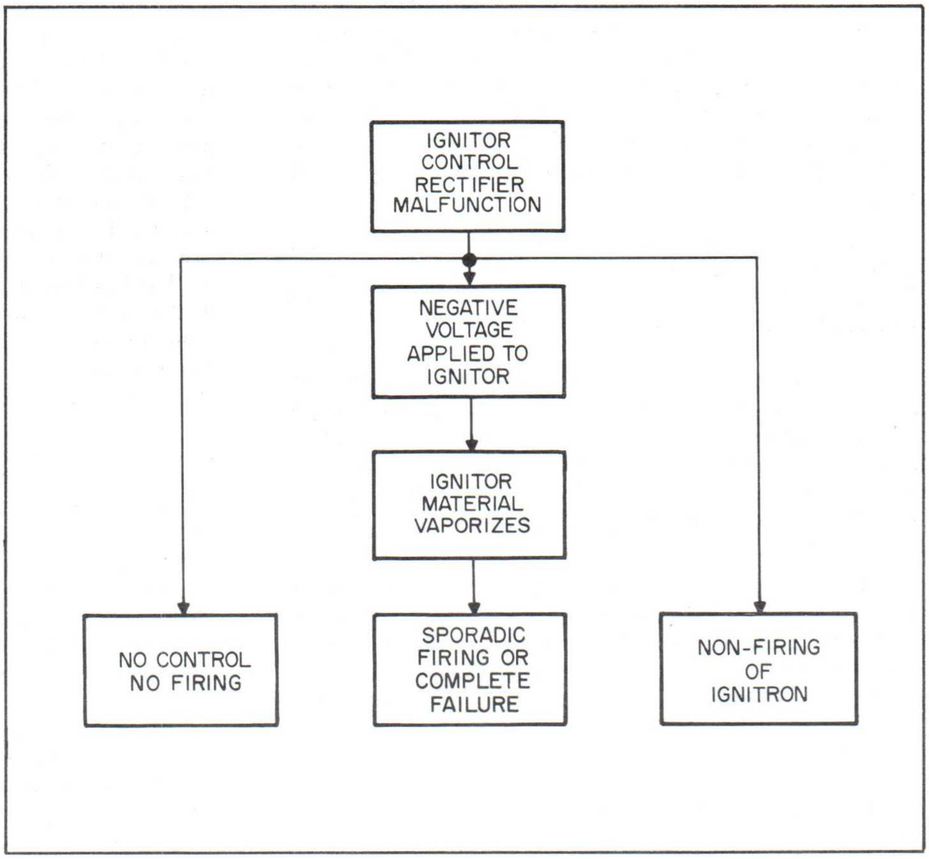


Figure 9. Effects of Malfunction in Ignitor Control Rectifiers

PREVENTIVE MAINTENANCE CHECK

BE SURE THIS IS DONE	BE SURE THIS IS NOT DONE
1. Water supply and controls adequate.	1. Water and thermostat power shut off immediately after shutdown.
2. Allow tubes to cool before shutting off water and power to thermostat controls.	2. Overload tubes.
3. Mount control to avoid excessive vibration.	3. Replace ignitrons without checking rectifiers or firing tubes.
4. Keep terminals clean and tight.	4. Store tubes on side.
5. Check tubes periodically.	5. Rough handling of tubes.
6. Keep records of tests and equipment performance.	
7. Store ignitrons in an upright position.	

Figures 7, 8, and 9 illustrate the actual resultant malfunction or breakdown of the ignitron and the chronological sequence of events which lead up to it. A preventive maintenance program applied through periodic inspection will reveal these conditions as they develop. Immediate correction thereof will tend to eliminate most ignitron failures and untimely equipment breakdown.

b. WATER TEMPERATURE.

(1) The cooling system of an ignitron can be compared to an automobile engine cooling system. Similarly, the cooling coils or water jacket in an ignitron is comparable to the water jacket in a liquid cooled automobile engine, and the flow of water through these coils or water jacket is used to maintain the operating temperature below a maximum limit.

(2) It is obvious that the lower the temperature of the coolant before entry into the coils or water jacket, the lower will be the rate of flow required to maintain a safe operating temperature.

(3) Due to a time lag between the transfer of heat from the ignitron to the water, it is necessary to allow the cooling water to flow through the ignitrons for a period of time after the anode power has been turned off. Non-compliance with this rule can lead to tube overheating immediately after power shut down.

(4) For example, water should be circulated through National NL-1051A and NL-1052A type ignitrons for at least 15 or 20 minutes after anode power has been removed. This period of time should be at least 20 to 30 minutes with type NL-1053A ignitrons.

c. THERMOSTATS.

(1) National ignitrons are equipped with a flange for mounting an over temperature protection thermostat and/or a water-saving thermostat. Figure 10 shows a typical installation where one ignitron is equipped with an automatic overheat shutdown thermostat, and the second ignitron is equipped with a water-saving thermostat.

(2) Water saving on NATIONAL® ignitrons can be accomplished in two ways:

(a) By use of a water-saver thermostat paralleled by relay contacts as shown in figure 10. The contacts of the thermostat should be shorted by a pair of auxiliary contacts closing when the weld initiating switch closes, and held closed during the weld cycle. This mode of operation starts the water flow immediately when the weld initiating switch is closed and provides maximum cooling. The thermostat then functions to provide water flow during part of the non-conducting period to remove the heat stored in the ignitron and cuts off the water when the ignitron is cool. With this type of operation the full rated load of the ignitron is available since the water starts flowing prior to the beginning of the conduction period. It also permits saving of tip and transformer cooling water by controlling this water with the same solenoid water valve.

(b) By using only the protection thermostat, C4391N7-52 or C4391N7-59, and partially closing a hand valve in the cooling water line to give only the flow needed for adequate cooling on the particular job. The hand valve should control water flow to only one pair of ignitrons. Tip and transformer water flow should not be reduced. If water flow is reduced too far the protection thermostat will open and thereby prevent damage to ignitrons.

(3) Such occurrences as fluctuating water pressure, irregular flow, and temperature rise of cooling water no longer cause unnecessary shutdowns and unnecessary loss of production time. The thermostat will shut down the equipment only when the

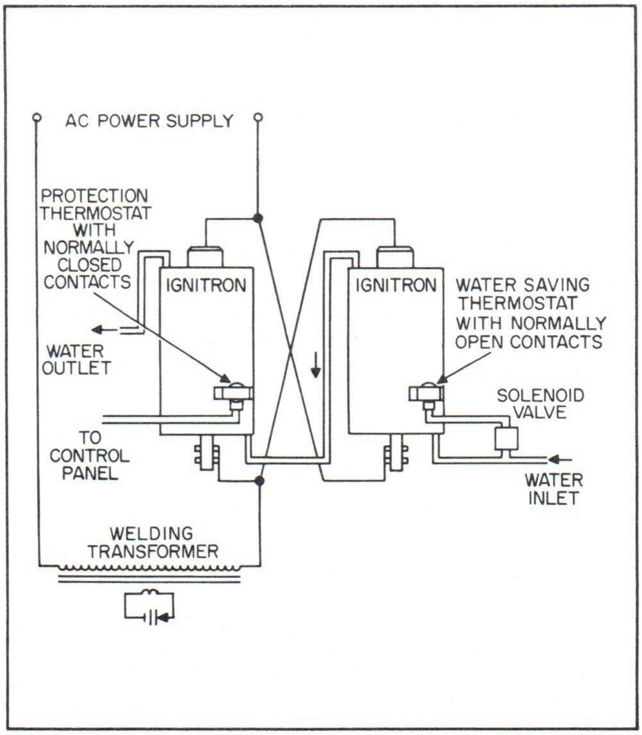


Figure 10. Thermostats

tube temperature rises high enough to endanger the ignitrons. As the cooling water does not come in contact with the outer can there will be no condensation and consequent damaging drip from the ignitron. Nor is it necessary to shut off the water during down time to prevent condensation on the ignitron.

(4) The greater thermal capacity of the NATIONAL® construction permits greater maximum averaging time, for increased welding capacity. On the B and C sizes, it has been increased by 50% and on the D, by 100%.

(5) Spare tube stocks can be reduced to a minimum. Since the thermostats are demountable, tubes are purchased without thermostats and can be used to replace old style tubes or, with the addition of a thermostat can be used for thermal protection. It is necessary to stock only one style tube for each size used.

(6) All sizes use the same thermostats. A small thermostat stock is adequate for proper maintenance of all welders. All thermostats are supplied with the necessary mounting clamps. No delicate adjustment is necessary on the thermostats before mounting.

(7) The high efficiency of the cooling system makes possible maximum water saving. A substantial water saving, in excess of 90%, for many applications, can be obtained by reducing the water flow by means of a manually operated water valve. This is possible because the coil construction maintains turbulent flow at low rates of flow. The protection thermostat protects the ignitrons and shuts down equipment if reduction has been excessive. Additional savings are possible during down time with a water-saver thermostat and solenoid valve.

(8) There are no stagnant spots in the cooling system to build up sediment deposits. The coils are self flushing and all sediment is flushed down the drain. This eliminates loss in cooling efficiency due to such deposits and decreases maintenance costs.

(9) Table I lists the actual cooling requirements of size B, C, and Jumbo C National Electronics ignitrons. The thermostat mounting plate on National Electronics ignitrons is solidly brazed to the inner cylinder or copper cooling coils thereby providing positive temperature sensing with a minimum of thermal lag.

TABLE I. COOLING REQUIREMENTS OF B, C, AND JUMBO C IGNITRONS

SIZE	AMPS (DC)	INLET WATER (TEMP °C)	100% LOAD		50% LOAD	
			WATER FLOW REQ'D (GPM)	PRESSURE DROP PER TUBE (LBS PER SQ IN.)	WATER FLOW REQ'D (GPM)	PRESSURE DROP PER TUBE (LBS PER SQ IN.)
B	56	15	0.25	0.4	0.063	0.1
		30	0.50	0.75	0.125	0.2
		40	1.50	3.00	0.25	0.4
C	140	15	0.375	0.6	0.125	0.2
		30	0.5	0.9	0.25	0.4
		40	1.25	4.0	0.5	0.9
JUMBO C	220	15	0.875	1.5	0.375	0.6
		30	1.375	5.0	0.875	1.5

1-3. MAINTENANCE HINTS.

a. GENERAL. Obviously, the basic conditions which lead to tube failure are those to which preventive maintenance should be applied through periodic inspection. If any of the conditions outlined in the following paragraphs are found to exist, they should be corrected as soon as possible.

b. FOUR COMMON CONDITIONS THAT WILL CAUSE IGNITRONS TO OPERATE IMPROPERLY.

(1) Operating the control when only one of the two ignitrons is conducting. Long weld time or repeated short welds under these conditions will produce high current surges, which may destroy the operating ignitron, and in some cases may cause insulation puncture in welding transformers. This condition is most commonly referred to as half cycling and can result from one or more of the following faults:

(a) Operating welder with open or high resistance secondary circuit. This condition is often caused by broken or badly worn electrodes, low electrode pressure, dirty or scaly stock, poor electrical contact joints in the secondary circuit, or frayed or broken gun cables. Such an open or high resistance secondary may reduce the demand current on the ignitrons to a point so low that one or the other tube will not ignite or may go out during its conducting half cycle. An auxiliary load resistor connected across the primary of the welding transformer will prevent damage to tubes and transformer from this fault.

(b) Operating welder when one of the ignitor firing thyratrons has failed or when one of the dry type rectifiers in the ignitor circuit has failed.

(c) Operating a relay fired welder with burned or broken ignitor firing relay contacts, or when relay is bouncing or chattering.

(d) Operating welder equipped with phase shift heat control (especially on heavy welding job with long weld time) when unbalanced firing is occurring. This is most often due to improper adjustment of power factor correction adjustment, or fault in ignitor circuit to one ignitron such as high resistance contact in socket of one ignitor firing thyratron.

(e) Operating welder when one ignitron has open or shorted ignitor, or when one ignitor fuse has blown.

(2) Operating the control without sufficient water flow or no water flow. Repeated operation of equipment under such conditions can sufficiently overheat the tube to cause its glass-to-metal seals to leak air and make the tube inoperable, In severe cases, the glass may melt or break. These cases are more frequent and generally more destructive where protection is dependent on a flow switch, because the time lag of some flow switches is so great. Thermostat protection has a much more rapid response, thus greatly reducing the possibility of damage.

(3) Mounting of ignitrons in control.

(a) Ignitrons should always be mounted so as to be as nearly vertical within 4-5 degrees as possible. If the tube is tilted in any direction, excessive immersion or insufficient immersion of the ignitor can result. In either case, shorter tube life and erratic operation can result.

(b) Tilting the tubes to match ignitor cold resistance will rarely, if ever, improve tube operation; in fact, in most cases it will shorten tube life or produce erratic operation. Ignitors are positioned in manufacture so as to have the proper immersion depth with the tube in a vertical position.

(c) All connections to the tube should be clean and tight because any looseness can result in high resistance connections which will generate heat and may damage tubes. Lock washers should not be removed or left off because without them tight joints can become loose under vibration.

(4) Statistics show the most frequent cause of ignitron failure is rough handling and accidental destruction from such things as short circuiting by foreign articles in the control panel or tubes being drenched with cold water while they are still hot from recent operation. These statistics show that comparatively few ignitrons die of the normal cause; i.e., gradual eroding away of the ignitor through billions of firings until it becomes thin enough to burn off. Contrary to some opinion, cold resistance of ignitors does not constitute a method of matching tubes. Peak volts and peak amps required to start an arc spot determine the condition of an ignitor and are not necessarily directly related to cold resistance. Seldom, if ever, can balanced firing be achieved by matching ignitor cold resistance. Some ignitors with very low cold resistance such as 5 ohms have been produced that have very satisfactory peak volt ampere requirements for firing. The same is true of some ignitors with resistances much higher than the average. If unbalanced firing exists, it is most frequently traceable to some circuit difficulty.

c. IGNITRON TROUBLE-SHOOTING SYMPTOMS.

(1) Severe electrode spitting, with well dressed electrodes and normal air pressure, suggests a gassy ignitron.

(a) Make certain that water is flowing, disconnect both ignitor leads, and allow points to close. If sparking occurs when points touch work, one of the ignitrons may be gassy. The gassy tube can often be identified by leaving the ignitor leads off and observing the ignitrons for glow in the top glass seal.

If one is glowing under these conditions, that tube is gassy.

(b) In some cases, the glow observation method is not workable because of excessive blackening of top glass seal or glow discharge occurring in tube where it cannot be readily seen through glass seal. To determine which tube is gassy, disconnect both ignitor leads, energize panel, and check for voltage across primary of welding transformer. If any voltage appears, one ignitron is gassy. De-energize panel and disconnect anode lead of one ignitron, re-energize panel and repeat the voltage check. If voltage is gone, the disconnected tube is bad. If voltage is still there, the connected tube is probably bad. De-energize panel and disconnect anode lead of other tube. Re-energize panel and repeat voltage check again. If voltage is still there, the transformer or other circuitry adjacent to welding transformer is grounded or shorted, and probably neither tube is bad.

(2) Repeated line breaker tripping and/or abnormal groaning of welding transformer indicates half cycling. Under these conditions, weld heat will vary from normal.

(a) The non-firing tube can usually be found by observation.

(b) A severe unbalance of control when operating on high current long weld time jobs will cause similar symptoms.

(c) Half cycling is more often due to ignitor circuit rectifier or ignitor firing thyratron failure than ignitron failure. These components should be checked before ignitron is replaced.

(d) When half cycling is occurring, de-energize the panel and disconnect ignitor leads from tubes. Check cold resistance of ignitor to cathode bus. If resistance of either ignitor is below 10 ohms or above 150 ohms, this may be the trouble, and that ignitron should be checked in another panel or sent to the tube manufacturer for testing.

(3) Electrode spitting on welder for short time after overnight or over-weekend shutdown.

(a) Occasionally, welder will show this symptom for a short time, and then operate satisfactorily until the next day, only to do it again. This is usually a gassy ignitron, which after a few conductions cleans itself up. To determine which is the gassy tube, you must proceed as in Item (1) above, but it must be done before welder is put into operation after long shutdown.

(b) This symptom can also result from a moisture ground in welding transformer.

(4) Occasional half cycling and intermittent transformer groaning with fluctuation in weld heat accompanied by occasional cold welds.

(a) This is often the symptom of normal ignitron failure at the end of life. The gradual erosion of the ignitor will become apparent by this occasional malfunction of equipment and will become more frequent. A cold resistance check of the ignitor will show that its resistance has gone above 150 to 200 ohms or below 10 ohms and the tube should be tested or replaced.

(b) This symptom can also indicate failure of one of the ignitor firing thyratrons. Such trouble caused by thyratrons is a result of peak emission slump in the thyratron. An average emission check of the thyratron will not indicate the bad tube. The bad thyratron can often be detected by observation. If one tube is glowing intermittently bright and dim, or glows with a distinctly different color than similar tubes, this is likely the faulty tube and should be replaced.

1-4. TESTING IGNITRONS.

a. GENERAL. The following tests can be used to determine whether the ignitor has become "wet" or whether gas has formed in the tube.

CAUTION

Safety precautions should be taken during these tests.

b. IGNITOR TEST. (See figure 11)

(1) Remove tube from equipment.

(2) Connect ohmmeter to ignitor stud and cathode bus. (Ohmmeter R x 1 scale).

(3) Hold tube vertical with cathode bus down. The reading should be 10-200 ohms.

(4) Slowly tilt tube toward ignitor stud about 15°, then tilt about 15° in opposite direction. The resistance should vary smoothly down and up.

(a) If resistance in step (3) above is below 10 or above 200 ohms, this is probably the tube causing trouble.

(b) If resistance change is erratic (shows sudden changes), the ignitor is broken or wetted (bad tube).

(c) If ohmmeter reading is either 0 or infinity, ignitor has been destroyed.

(5) Several tubes should be tested in a similar manner, including new tubes in order to provide the serviceman with the "feel" exhibited by this test.

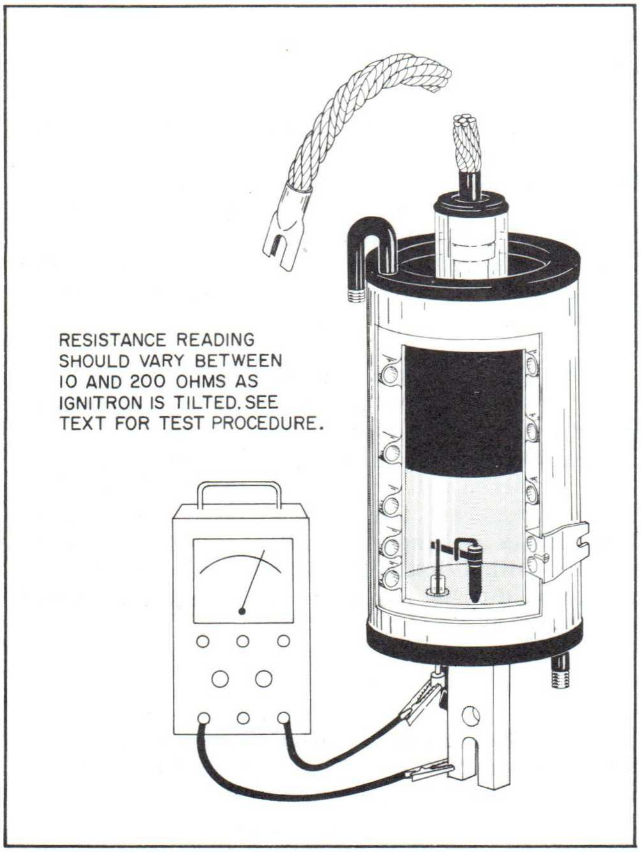


Figure 11. Ignitor Resistance Test

(6) If the test shows that the ignitor is wet, the tube may operate satisfactorily for a while; however complete failure or sporadic operation is inevitable.

(7) Wet ignitors indicate that the tube was probably operated at temperatures in excess of ratings, or that sidewall arcing had occurred. An investigation should be made to correct this condition.

c. VACUUM TEST. (See figure 12)

(1) PRELIMINARY TEST PROCEDURE.

(a) Use a hand-held spark coil capable of generating a 1/2 to 3/4 inch spark. These spark coils are available from Scientific Supply outlets.

(b) After the tube is cool, disconnect the anode cable terminal from the panel.

(c) Connect the cathode (tube envelope) temporarily to ground in order to protect the circuit insulation.

(d) Touch the spark coil tip to the anode cable. During this test, a hazy blue or gray glow that flashes or appears intermittently may be visible through the glass anode seal. This is a normal phenomena.

(e) If sustained sparking is visible in the space between the glass seal and the inner anode lead, the tube may be gassy. Remove it from the panel and perform the high potential test procedure.

(f) If sustained sparking is not visible, the tube may still be gassy, and the test should be continued.

(g) Bend the anode cable so that the terminal is approximately 1 inch from the tube cylinder.

(h) Place the tip of the spark coil against the anode terminal and press it slowly toward the tube cylinder. A spark should jump between the terminal and the tube cylinder before the gap reaches 3/16 inch. If the gap has to be decreased below 3/16 inch to make the spark jump, the tube may be gassy and should be removed from the panel for high potential testing.

(2) HIGH POTENTIAL VACUUM TEST. (See figure 13)

WARNING

Extreme safety precautions must be exercised because of HIGH VOLTAGES involved.

(a) Energize tester with secondary of H.V. transformer open circuited and variable transformer at 0 volts. Increase voltage to maximum and record primary current in H.V. transformer. This current should be very small.

(b) Reduce voltage to 0 volts. DE-ENERGIZE TESTER.

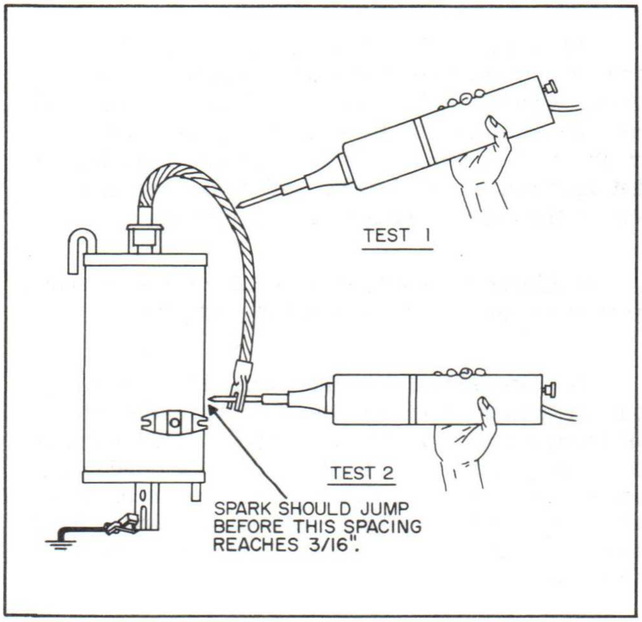
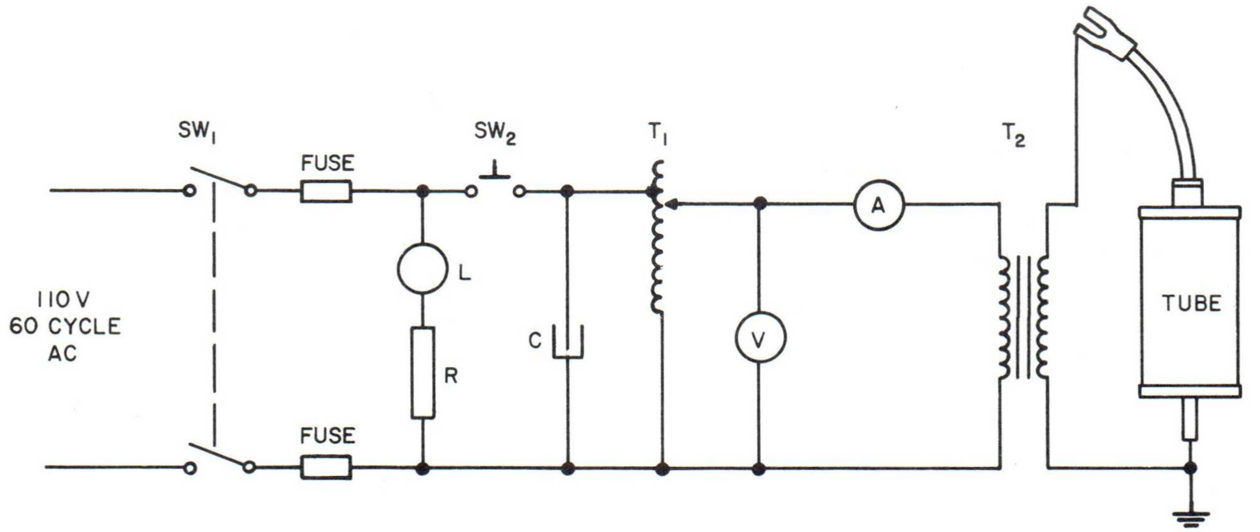


Figure 12. Preliminary High Potential Vacuum Test



A – Ammeter 0-5 Amps. AC

C – Capacitor .25 mfd 400V

F – Fuse 1 Amp. 230V

L – Neon Lamp .25W

R – Resistor 12K .25W

SW_1 – Switch D.P.S.T. 120V 2 Amp.

SW_2 – Switch S. P. Spring Loaded N. O.

T_1 – Variable Transformer 0-135V 1 Amp.

T_2 – High Voltage High Impedance Transformer Pri., 120V; Sec. any voltage between 6,000 and 12,000.

V – Voltmeter 0-150 V AC

A suitable enclosure can be constructed of wood or dielectric material. Care should be exercised so as not to leave any energized wires or parts accessible for accidental contact.

Automotive high voltage ignition cable is recommended for the leads connecting the tube to the H.V. transformer secondary.

Figure 13. Test Setup For High Potential Vacuum Test

(c) Support the ignitron tube in a vertical position with the cathode bus down.

(d) Cathode bus should be grounded so that only the anode lead can be elevated to high potential.

(e) BE SURE TESTER IS DEAD. Connect the high voltage secondary of the H.V. transformer to the anode lead. BE SURE TO CONNECT GROUNDED SIDE of H.V. transformer secondary to cathode bus of tube.

(f) Use variable transformer to gradually increase voltage across tube (always starting at 0 volts), until maximum is reached.

1. If the steady current is not in excess of open circuit current, the tube has good vacuum.

2. If a steady current in excess of the open circuit current is read, the tube has poor or no vacuum. (Tube is bad.)

3. Occasional flicks of the ammeter may be observed while elevating voltage. This is caused by arcs from small droplets of mercury on internal parts and does not indicate poor vacuum.

4. If steady current is allowed to flow for some period, gas can sometimes be cleaned up and tube will appear to pass repeat test. This tube is not operable because gas will reappear after some storage period.

(g) Reduce voltage to zero, de-energize tester, and remove tube.

1-5. COPPER COIL COOLING VERSUS WATER JACKET BATH COOLING.

National Electronics tubes use copper tubing coils for water cooling. The advantages of this construction are listed below.

a. COPPER COOLING COIL. The high conductivity of copper, greater thermal mass of assembly, and turbulent flow of the cooling water through the tubing are utilized to give maximum cooling efficiency.

b. INNER WALL TEMPERATURE CONTROLLED FOR PARTICULAR AREAS. Close spacing of coil is maintained on lower section for cooler wall where mercury condensation is desired. Wide spacing on upper section eliminates danger of arc-backs by preventing mercury condensation near anode.

c. NO SWEATING—NO DRIPPING WATER TO INJURE OTHER COMPONENTS. Cooling coils and outside of inner can are covered with an insulating coating. This coating plus the outer can prevent outside air contact with water cooled parts and eliminate water condensation on tube.

d. POSITIVE TEMPERATURE SENSING. Copper thermal block and thermostat mount are brazed and soldered to inner can. No variations in temperature sensing will result from aging or impurities in cooling water. Even muddy water does not impair the accuracy.

e. NO SEDIMENT DEPOSITS OR FLOW RESTRICTIONS. The sweeping bends of the cooling coil produce free highly turbulent flow, are self-flushing, and maintain high cooling efficiency.

NOTE

These advantages found only in NATIONAL ELECTRONICS' coil construction ignitrons give longer trouble-free service, less down time, and consequently, lower maintenance costs. Because of higher cooling efficiency, National ignitrons can be used with warmer cooling water and less cooling water than other makes.

Part II
THYRATRONS AND RECTIFIERS

2-1. GENERAL.

a. Thyratrons and rectifiers are gaseous electronic tubes which are used extensively in industrial control equipment. Unlike ignitrons which have cold cathodes, thyratrons and rectifiers are hot-cathode tubes in which the source of electrons is a coated metal cathode heated to a temperature of several hundred degrees.

b. The basic elements of thyratrons and rectifiers are shown in figures 14 and 15. Both classes of tubes contain (1) a cathode (electron emitting element), (2) an anode (electron collecting element), (3) a gas (to assist current conduction through the space), and (4) an envelope. The latter is usually glass, although metal envelopes are used in larger tubes. The cathodes in most gaseous tubes are directly heated, i.e., the electron emitting material is applied directly to the heating element or filament.

c. In addition to these elements, thyratrons contain an additional element; the control grid, which is physically located between the cathode and anode. The control grid will be described in a latter section.

d. The gas fill used in thyratrons and rectifiers gives these tubes the distinguishing characteristic of being able to conduct rated electron emission at very low anode potentials (in the order of 10 to 20 volts). The gases most commonly used are xenon, argon, and mercury-vapor or a combination of mercury-vapor and xenon or argon.

e. The high current capabilities at low anode potentials of gaseous tubes are possible because the electron space charge is neutralized by positive ions. The positive ions are formed when electrons emitted from the hot cathode collide with the gas molecules. When electrons bombard gas molecules with sufficient energy, the impact removes an electron from the molecule and leaves a positive ion. The resulting positive ions migrate slowly toward the cathode and neutralize the electron space charge which would otherwise exist. This process is called ionization of the gas and the potential at which it occurs is the ionization potential (in the order of 10 to 20 volts).

f. The important features of gaseous tubes are:

(1) High current carrying capacities for a given physical size.

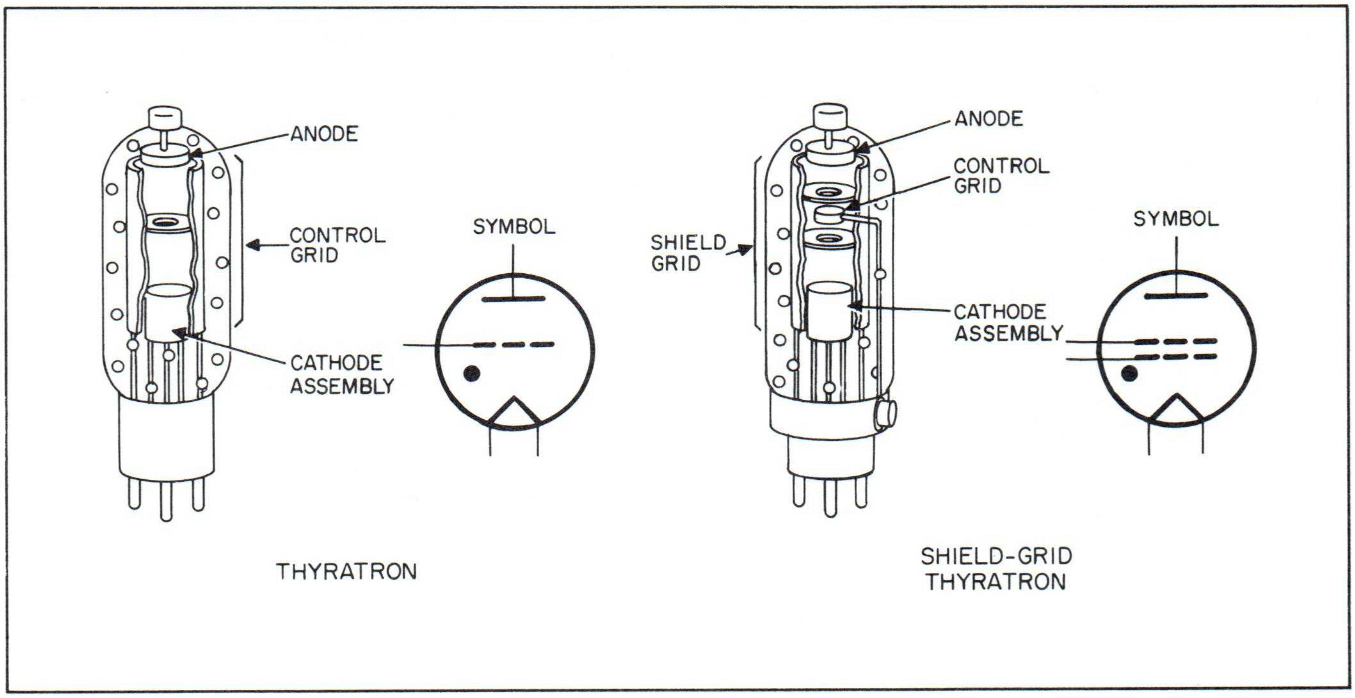


Figure 14. Typical Thyratron

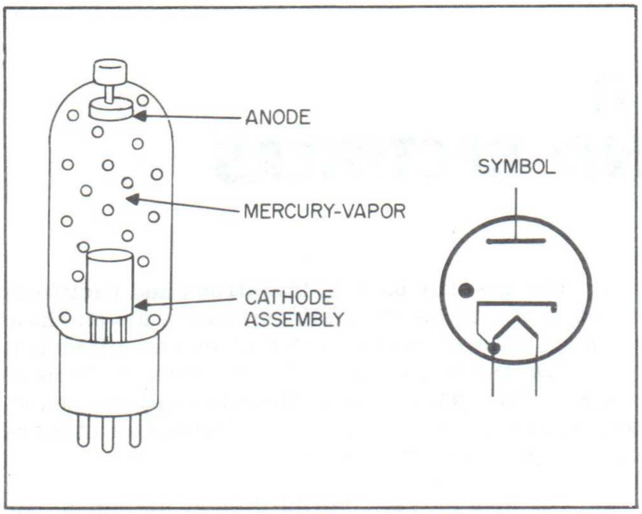


Figure 15. Typical Rectifier

(2) High efficiencies.

(3) Rugged construction.

(4) Low heater power.

(5) Low initial cost.

(6) Low internal voltage drop.

(7) Good regulation.

g. Some important electrical ratings of gaseous tubes are:

(1) Maximum peak anode current (instantaneous value).

(2) Maximum average anode current (dc meter value).

(3) Maximum peak inverse anode voltage (instantaneous value - anode to cathode).

(4) Thyratrons only - maximum forward anode voltage (peak or instantaneous value - anode to cathode).

2-2. THYRATRONS.

a. The preceding basic description of gaseous tubes is also applicable to thyratrons. However, where rectifiers are diodes, thyratrons are generally three-element tubes (triodes) with a control grid being the third element. In some thyratrons additional grids are used for special purposes.

b. The control grid can be one of several different designs. Basically this element is a metal or graphite structure with one or more apertures through which electrons pass from cathode to anode. It can be a piece of metal perforated with a slot or several holes, a grided structure constructed with many parallel wires, or a graphite wafer with suitable openings.

c. The action of the thyratron grid is quite different from that of a high-vacuum tube grid. In a vacuum tube, the grid controls the flow of current smoothly both increasing and decreasing; whereas, in a thyratron, the grid can only control the initial point at which anode current starts and then the grid loses control until current falls to zero (usually at the end of the half cycle). Thus the action of the grid is a full off to full on control such as a switch.

d. This trigger-like action of the control grid is explained as follows: As long as the grid is at a voltage more negative than the "critical" grid voltage, electrons are repelled and there is no flow of anode current. As the grid voltage is made less negative and as soon as it approaches the "critical"

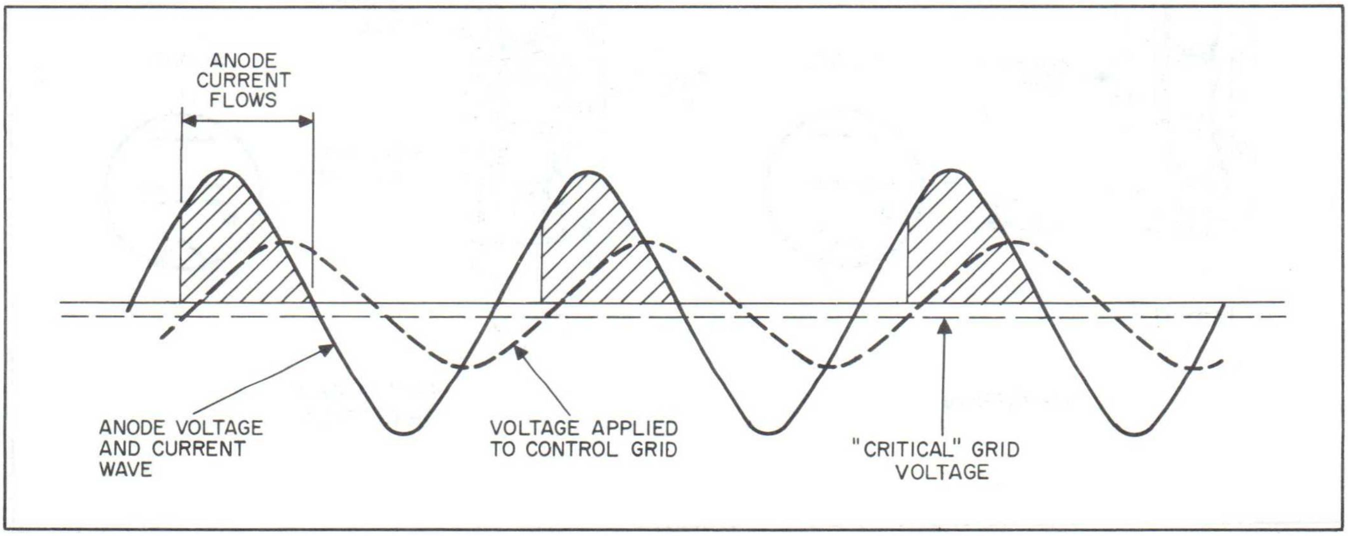


Figure 16. Controlling Thyratron Anode Current

grid voltage, electrons pass through it and anode current begins to flow. The flow of electrons, as in rectifiers, creates positive ions which neutralize the negative space charge. The positive ions form a cloud (or sheath) around the grid and it loses control until the plate current is reduced to zero and the ions disappear.

e. This unique feature of thyratrons, i. e., the trigger action of the control grid is used extensively in industrial control applications. When ac voltage is applied to a thyratron, the plate voltage is negative for one-half of each cycle. The grid regains control during this period. By properly designing the grid control circuitry, the thyratron can be made to conduct at any time during the positive portion of each cycle, the only requirement being that the anode voltage must be greater than the ionization potential of the gas fill (approximately 15 volts).

f. Figure 16 is a graphical illustration of a thyratron used with an alternating current supply. By changing the time or point at which the grid voltage equals the "critical" voltage, the "firing" point can also be changed, and the average current controlled from a very low value to the maximum rating of the tube.

g. Another of the very desirable features of thyratrons is that the control grid requires very little power to control it; i. e., it draws very little current. Thus, the thyratron may be used to precisely control large amounts of power in the load with very little power in the control circuit.

2-3. RECTIFIERS.

a. Gaseous rectifiers are two element tubes and are used primarily in power supply equipments to rectify or convert alternating current to direct current. As, in the case of ignitrons, rectifiers conduct current only when the anode is positive with respect to the cathode. Unlike ignitrons in which the point of conduction can be controlled by means of the ignitor firing time, rectifiers conduct over the entire positive half cycle of the ac voltage. The current delivered by the rectifier is a function of the load connected to it.

2-4. OPERATING SUGGESTIONS.

a. THYRATRONS. The filament voltage, filament heating time, peak anode current and average anode current considerations of thyratron tubes also apply to rectifier tubes, and are therefore discussed in subparagraph b following. Aside from these four considerations, there are five additional important considerations which must be taken into account if maximum operating efficiency and long life is desired of thyratron tubes. These considerations are:

(1) Maximum Peak Forward Voltage. This is the instantaneous value that would be observed on an oscilloscope. Exceeding the peak forward voltage may result in loss of grid control.

(2) Grid Control Characteristic. This characteristic is defined in the technical data sheet for any thyratron tube types by means of a curve showing a range of characteristics. This curve defines the min-max grid characteristics within which all tubes will fall when operated within the published temperatures and heater voltages. The manufacturer of electronic equipment will usually provide sufficient grid control voltage and a sufficiently steep wave to provide accurate control of the firing point regardless of the characteristic of the particular tube being used as long as its characteristic lies within the published range.

(3) Maximum Commutation Factor. This limitation applies particularly to inert gas filled thyratron tubes and must be observed if gas clean-up is to be avoided. It is concerned with the amount of ionization present in the tube at the moment anode current ceases and inverse voltage is applied. High inverse voltages attract the remaining positive ions and generate great velocities which may result in ion bombardment of the elements and gradual gas clean-up. Commutation factor is defined as the rate of change of current (just before anode current ceases) in amperes per microsecond times the rate of application of inverse voltage in volts per microsecond.

(4) Deionization Time. This is often called "recovery" time and is defined as the minimum time that must elapse after anode current has ceased before the grid can once again assume control of the thyratron tube. This time is required for the positive ions in the tube to reach the walls and electrodes and lose their charges.

(5) Maximum Ac Short Circuit Current. Often this is called the "fault" current rating in the tube. If the equipment is designed or installed in such a way that short circuit current may exceed the rated value, the tubes may be unable to stand up under short circuit conditions and furthermore the commutation from one tube to another in a rectifier circuit is speeded up to the point that arc-back and short tube life become distinct possibilities.

b. RECTIFIERS.

General. There are principle considerations which must be complied with in order to obtain maximum rectifier tube service. These characteristics are: filament or heater voltage, filament or cathode heating time, peak anode current, average anode current, and peak inverse anode voltage.

(1) Filament or Heater Voltage. Operating the heater or filament at too low a voltage accelerates destruction of the cathode because of the inability of the cathode to supply the required emission. Operating the heater or filament at too high a voltage

shortens the life of the cathode and usually results in premature filament burn-out.

(2) Heating Time. Insufficient filament or cathode heating time permits operation of the tube before full emission is available from the cathode. Sparking and gradual destruction of the cathode usually is the result of this condition.

(3) Peak Anode Current. This is the maximum instantaneous value such as would be observed on an oscilloscope. If the peak anode current exceeds the rated value, there is a possibility that insufficient electrons will be available from the cathode and "sparking" or "sputtering" may occur and destroy the cathode rather rapidly.

(4) Average Anode Current. This is the current that would be indicated by a dc ammeter in the anode circuit. The heating of the anode is approximately proportional to dc anode current since arc-drop within the tube is relatively constant. Exceeding the maximum rated average anode current will shorten the life of the tube because of excess heating.

2-5. MAINTENANCE HINTS. — THYRATRONS.

a. SOME COMMON CAUSES OF THYRATRON FAILURES IN INDUSTRIAL CONTROLS:

(1) The most common cause of thyratron failure, both in resistance welding control and motor speed control applications is poor electrical contact between tube and socket. The anode current added to the high filament current makes necessary very positive connection between socket and tube terminals. Lug base and panel mounted tubes overcome this problem. The rapid adoption of the lug base tube is due to its elimination of this poor contact problem without sacrifice of quick change and rugged mounting features.

(a) Even a small amount of resistance caused by low spring pressure or oxidation of contacts produces sufficient voltage drop at these high currents to produce short tube life. This condition becomes rapidly worse because of excessive heat generated at the poor contact point by the voltage drop at these high currents.

(b) The reduction of filament power due to the resistance developed because of poor contacts lowers the cathode temperature. This reduces the cathode emission (current carrying ability) and subjects the tube to self-destruction from positive ion bombardment.

(c) Filament voltage delivered to pin type tubes can be checked by raising the tube slightly in the socket and measuring voltage on the filament pins. In extreme cases this fault may result in pin solder melting.

(2) The second most prevalent cause of thyratron failure is operating the tubes with low filament supply voltage. If the tube is allowed to start with filament voltage below normal published value, the cathode does not reach full emission temperature, and the cathode will be progressively destroyed by positive ion bombardment. Filament voltage should be checked on tube pins or on tube socket connections while equipment is operating to insure that voltage is correct under load conditions. Filament transformer taps should be adjusted so as to obtain required voltage under full plant operating load.

(3) Another frequent cause of thyratron failure is operating equipment before tubes have had time to heat.

(a) When thyratrons are operated before they have had time to become sufficiently heated, the result can be erratic control. The tube can be made inoperable due to sputter or sparking of the cathode (destruction of cathode coating material). After relatively few sputters, the tube may no longer conduct peak rated current. The visual evidence of sputter is excessive glow in tube accompanied by falling particles inside tube. Always turn on filament power for the minimum value of specified heating time for the slowest heating tube in equipment before operating equipment.

(b) When thyratrons are used in phase shift heat control applications, too short a warm-up time can produce changes in percent heat, and at times, unbalanced firing.

(4) Restriction of cooling air flow.

(a) Control equipment cabinets are designed with sufficient ventilation to allow air passage through the cabinet to cool the tubes and other components. Restriction of this air flow may cause tubes to over-heat and result in loss of control by thyratrons. Eventual destruction of the tubes and other components may result, as well as malfunction of equipment. The louvers and openings in the cabinet are to allow for passage of this cooling air and should never be covered or restricted in any way.

(5) Excessively high filament voltage. Continued over-voltage such as +15% will materially shorten emission life by boiling off cathode material.

b. SYMPTOMS OF THYRATRON TROUBLE.

(1) RESISTANCE WELDING CONTROL.

(a) Failure of machine to go through sequence of operation: This most often indicates failure of one of the small thyratrons in the timer panel. The faulty tube can generally be found by observing which operational sequence does not function and replacing the tube or tubes controlling that sequence function.

(b) Intermittent changes in weld heat where thyratrons are used for ignitor firing: This generally indicates that one or the other firing thyratron is not passing sufficient peak current to fire the ignitor or has lost control and is firing the ignitron without grid signal being applied. The faulty tube can generally be found by observation. Not firing steadily during weld time would suggest a faulty thyratron or ignitron. Firing after the weld time is over suggests a faulty thyratron.

(c) Welder half cycling is indicated by the welding transformer groaning. This may be accompanied by one firing thyratron not conducting. This can be observed easily as one tube will show no glow during weld time. If new tube doesn't fire either, check ignitor fuse, and ignitor circuit for open. Check also for bad socket or low filament voltage.

(2) MOTOR SPEED CONTROL.

(a) Motor run-away.

1. If motor goes to overspeed and does not respond to speed reduction control, this suggests loss of grid control by one or more of the thyratrons. This can come from severe over-temperature condition through lack of cabinet ventilation. Loss of control can also be the result of repeated cold starting or arc-back of one or more thyratrons. Such faults may be caused by operating equipment when tubes have not had sufficient time to warm up or when filament voltage is too low.

2. Frequently loss of control can be traced to poor contacts in the speed sensing circuit, such as a bad potentiometer, dirty lens system on photo-sensing control, poor wiping contact on electrical and mechanical sensing systems. These types of trouble are often over-looked because their symptoms are the same as tube trouble symptoms.

(b) Intermittent speed variations

1. This is most often due to component failure or poor electrical connections in the grid control circuit of the thyratrons. Contrary to some opinion, changes in grid characteristics in thyratrons during normal life are rare.

2. Due to the self-compensating nature of most motor speed control equipments, such things as cold solder joints, intermittent opens or shorts in wiring, and partial or total grounds in wiring will be indicated by hunting or speed variations.

3. Operating equipment before tubes have had time to come to full emission temperature will produce hunting or variations in speed. However, hunting from this cause will disappear a short time after starting.

2-6. MAINTENANCE HINTS—GAS FILLED RECTIFIER TUBES.

a. COMMON CAUSES OF FAILURE.

(1) Most causes of malfunction and/or premature failure of rectifier tubes can be traced to cold starts under full load.

(a) Due to the comparatively short required warm-up time of most rectifier tubes, many equipments are not supplied with warm-up time delay devices. These equipments rely on the operator to allow adequate filament heating time before rectifier tubes are subjected to operating load. Applying plate voltage to the tubes before they had sufficient time to heat to operating temperature will cause the tubes to arc back and/or sputter. In most rectifiers, an arc-back in one of the tubes produces a short circuit in the rectifier which, if not cleared quickly, will seriously damage the tubes as well as other components.

(b) In cases where the rectifier is supplying DC to loads which are highly inductive in character, such cold starts can produce high voltage surges. These surges can destroy the tube by puncturing the seals and can also puncture insulation in the equipment.

(c) Tubes which contain mercury only may produce high voltage surges when operated below their rated minimum condensed mercury temperature because of insufficient mercury pressure.

(2) The second most common cause of rectifier tube failure is poor tube-to-socket electrical contact.

(a) As in the case of thyratrons, the addition of the anode current plus the high filament current must be carried by the tube-to-socket connection. This must be a very positive electrical connection. A small value of resistance at these high current carrying circuits produces an appreciable voltage drop which generates heat, thus increasing the voltage drop further. The result is progressive deterioration of socket contacts and lowering of filament voltage causing short tube life.

(b) Filament voltage delivered to pin type tubes can be checked by raising the tube slightly in the socket and measuring voltage on the filament pins. In extreme cases this fault may result in pin solder melting. Filament voltage on lug base and panel mounted tubes can be checked at the screw terminal binding posts. The screw terminals should be checked for tightness.

(3) Filament over-voltage accounts for short life experience with some rectifier tubes. Unless the over-voltage is extreme, very short life is un-

likely but a slow destruction of the tube over a period of months may occur.

(a) Filament over-voltage produces excessively high filament and cathode temperature. This high temperature will boil off the emissive coating from the cathode, thus reducing the tubes ability to conduct rated current.

(b) Extreme over-voltage can cause a rapid boil-off of cathode material and may be severe enough to cause the filament to burn out.

b. SYMPTOMS OF RECTIFIER TUBE FAILURE.

(1) Repeated blowing of line fuses or tripping of line breaker.

(a) This most commonly indicates arc back of one or more tubes. Repeated arc-backs are usually traceable to out-of-limit filament voltage or transient voltage on the line. Single arc-back when equipment is started after shutdown is almost always due to insufficient filament warm-up time before load is applied.

(b) Short circuit or ground in the load or load circuit will blow fuses or trip breaker, and if not corrected can destroy rectifier tubes and other components.

(2) Low DC voltage at rated load.

(a) This usually indicates high arc drop in one or more rectifier tubes. High arc drop will occur at the end of normal tube life, or be produced prematurely by out-of-limit filament voltage or repeated cold starts.

(b) In full wave or multiphase rectifiers, low DC voltage can result from loss of conduction of one or more rectifier tubes. The faulty tube can generally be located by observation. A gas tube which is not conducting will show no glow. A gas tube which is suffering from high arc drop will generally show a light color or yellowing glow.

(3) Repeated tube failures when tubes suddenly quit conducting but with filaments still hot can indicate loss of vacuum due to long-path discharge puncture, or arc-back over-heating. If the load is highly inductive, high transient voltages are the probable cause. The addition of surge suppressing devices may be indicated, such as thyrite or surge dampening resistors. Such modifications should be approved by the equipment manufacturer.

(4) Less common but occasional cases of tube and component destruction occur with highly inductive load applications from high voltage transients developing in the load. Such high transient voltages will cause long path discharge in the tubes which result in punctures of the tube vacuum seals and also cause insulation puncture in other components. The transients can be produced by nonsynchronous interruption of load current on solenoid applications or from some disturbance on the power line.

2-7. TESTING THYRATRONS AND RECTIFIERS.

a. GENERAL. Four simple checks of the condition of thyratrons and gaseous rectifiers are listed below. These checks are simple to perform and when performed properly will reveal faults in electronic equipment.

b. FILAMENT CHECK. Check the filament visually while the equipment is in operation, or shut down the equipment and check the filament with an ohmmeter. Keep in mind the fact that cold filament resistance is only a fraction of the hot filament resistance. In most cases the cold filament resistance is less than a tenth of an ohm.

c. AIR LEAK TEST. Remove the tube from the equipment, ground the cathode, and apply the tip of a spark tester to the anode. Sparking within the tube indicates that air has entered the tube. The type of sparking is referred to as a "hard spark" and it is similar to the spark drawn off the tip of the spark tester. Inspect for glass cracks on the tube. Cracked glass results in air entering the tube.

d. CATHODE SPUTTERING. While the tube is in operation, inspect the cathode for sputtering. This condition is recognized by sparks being emitted from the cathode which are actually particles of cathode material being separated from the cathode. This condition is indicative of tube failure.

e. TUBE SUBSTITUTION. Replace questionable tubes with tubes known to be in good condition and observe operation of the equipment. This check should be made when the other checks have presented no conclusive results, however this check should be brief so that possible trouble within the circuit will not damage good tubes.

2-8. LUG BASE DEPENDABILITY. (Check These Features)

a. Positive Contact:

(1) Spade terminals present large contact area.

(2) Contact not dependent on spring tension.

(3) Spade terminals coated with soft solder so screws cut their own contact seat.

b. Quick Installation: No pulling, twisting, prying. Simply slip tube lugs on terminal screws and tighten.

c. Only one (1) socket size for all lug base tubes.

d. No clamps, brackets, or additional supports required.

e. Heavy wire socket leads eliminate lead heating.

f. No front wiring required on panel.

g. No surfaces where dust collection can cause shorting or start corrosion.

h. Through panel mounting eliminates need for tube mounting shelf.

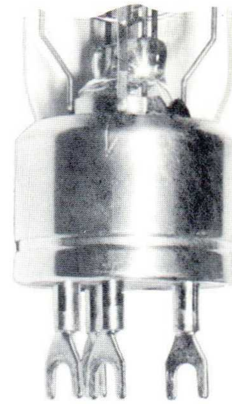
i. Free air circulation for better cabinet ventilation.

j. Makes practical a cabinet design with tubes external to other components, thus removing a major heat source from the enclosure.

SPACE FOR YOUR NOTES.

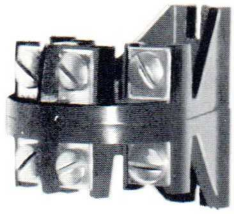
SPACE FOR YOUR NOTES.

LBTS-2 Lug Base Tube Socket



DESIGNED FOR DEPENDABILITY

A tube and socket combination which eliminates the possibility of poor tube to socket contact and gives maximum flexibility in equipment design.



Check These Features

1. Positive Contact:
   a. Spade terminals present large contact area.
   b. Contact not dependent on spring tension.
   c. Spade terminals coated with soft solder so screws cut own contact seat.
2. Quick Installation:
   No pulling, twisting, prying. Simply slip tube lugs on terminal screws and tighten.
3. Only one (1) socket size for all lug base tubes.
4. No clamps, brackets, or additional supports required.
5. Front wiring possible.
6. No contact surfaces where dust collection can cause shorting or start corrosion.
7. Simplified two screw mounting.
8. Through panel mounting eliminates need for tube mounting shelf.
9. Free air circulation for better cabinet ventilation.
10. Heavy bus socket leads completely eliminate lead heating.
11. Makes practical cabinet design with tubes external to other components, thus removing major heat source from tube compartment.

The lug sockets, as well as lug based tube types, are available from National Electronics, Inc.

See Your NATIONAL Tube Catalog for Types Available with Lug Bases

NATIONAL ELECTRONICS, INC.
A SUBSIDIARY OF EITEL-McCULLOUGH, INC.
GENEVA, ILLINOIS

Printed in U.S.A. 1/61

Part III

HANDLING AND STORING ELECTRONIC TUBES

Industrial electronic tubes are rugged long-lived devices. However, because their operating characteristics depend upon maintaining the original spacings and precision which is built into them, it is necessary to observe some care in handling them.

The following are a few "good practice rules" for handling industrial electronic tubes:

1. "This End Up" appearing on containers and cartons is not only for shipping but in most cases applies to all handling and storing of tubes.

2. Industrial electronic tubes have some glass or ceramic parts so they should not be subjected to bumps, shocks, or strains.

3. Instructions for warm-up time when tubes are originally installed into equipments should be followed. These instructions are necessary because mercury contained within the tubes becomes distributed over the internal parts during shipping and handling. If the mercury is not evaporated from these parts (anode, grid, and upper envelope areas) and condensed at the bottom of the tubes, arc-back may result and the tubes damaged.

4. When carrying ignitrons, the anode cable should not be used as a handle.

5. Excessive pressures or twisting should be avoided in placing pin-based glass tubes into sockets.

SPACE FOR YOUR NOTES.

SALES OFFICES

201 Town and Country Village
Palo Alto, Calif. 94301
Telephone 415 328-3786

2901 Wilshire Blvd.
Santa Monica, Calif. 90403
Telephone 213 870-8755

744 Broad St., Suite 423
Newark, N.J. 07102
Telephone 201 623-9250

NATIONAL ELECTRONICS, INC.

a varian subsidiary

GENEVA, ILLINOIS 60134

TELEPHONE 312 232-4300
TWX 910 237-1685

Printed in U.S.A.
SB—18A

CTP1

quick reference data

NATIONAL ELECTRONICS, INC.
INDUSTRIAL TUBES

IGNITRONS
THYRATRONS
RECTIFIERS

NATIONAL ELECTRONICS, INC.
a varian subsidiary
GENEVA, ILLINOIS
TELEPHONE 312 232-4300
TWX 910 237-1685

IGNITRONS

IGNITRONS are ignitor fired mercury pool rectifiers with high peak current capacity. Their ability to switch high currents at high speed makes it possible to control both the duration and amplitude of current required for consistent and accurate welding. They combine the high speed switching and high current capacity required for high voltage capacitor bank switching and crowbar operation.

Resistance Welder Service

TYPE	REPLACES*	SIZE	MAXIMUM DIMENSIONS — INCHES Rigid Length	Dia. ★	MAXIMUM RATINGS Maximum Demand KVA	Corres. Current DC Amps	Maximum Current DC Amps	Corres. Demand KVA	Maximum Avg. Time at 500V Seconds	Mounting
[1]NL-1001	——	•	9-3/16	2-5/8	150	4.9	9.0	50	14	Special
[1]NL-1005A	NL-1005	B	15-1/2	5-5/8	600	30.2	56	200	9	Conv.
[2]NL-1009A	7681	Jumbo C	16-1/2	5-1/2	1800	135	220	600	9.6	Conv.
NL-1031	——	B	6	3-9/16	600#	30.2	56	200#	9	Stud
NL-1032	——	C	8-7/8	3-9/16	1200#	75.6	140	400#	7	Stud
[2]NL-1051A	(6346), 5551A	B	13	3-1/4	600	30.2	56	200	13.5	Conv.
[2]NL-1052A	(6347), 5552A	C	15	4-5/8	1200	75.6	140	400	10.5	Conv.
NL-1053A	NL-1053	D-6000	21	7-1/8	3000	224	400	1000	11.0	Conv.
NL-1054A	7151, NL-1054	E	22	10-1/8	4800	486	900	1600	8.9	Special
[2]NL-1061	7669	B	11-5/8	3-1/4	600	30.2	56	200	13.5	Coax.
[2]NL-1062	7671	C	12-3/4	4-5/8	1200	75.6	140	400	10.5	Coax.
NL-1063	——	D-6000	20	7-1/8	3000	224	400	1000	11.0	Coax.
NL-1064	8205	E	22	10-1/8	4800	486	900	1600	8.9	Coax.
[2]NL-1069	7998	Jumbo C	15-7/8	5-1/2	1800	135	220	600	9.6	Coax.
[2]NL-1081	——	B-2000	13	3-1/4	1000	43.2	75	200	13.5	Conv.
[2]NL-1082	——	C-4000	15	4-5/8	2000	108	150	380	10.5	Conv.
[2]NL-1091	——	B-2000	11-5/8	3-1/4	1000	43.2	75	200	13.5	Coax.
[2]NL-1092	——	C-4000	12-3/4	4-5/8	2000	108	150	380	10.5	Coax.
NL-5550	5550	A	9-7/8	2.140	300	12.1	22.4	100	9.2	Clamp
[2]NL-5553B	(6348), 5553A	D	20-1/2	5-5/8	2400	192	355	800	5.5	Conv.
[2]NL-7673	7673	D	17	5-5/8	2400	192	355	800	5.5	Coax.

Frequency-Changer Welder Service

TYPE	REPLACES*	SIZE	MAXIMUM DIMENSIONS — INCHES Rigid Lgth.	Dia. ★	Inverse Anode Volts	MAXIMUM RATED CURRENT Max. Peak Amps	Corres. DC Amps	Max. DC Amps	Corres. Peak Amps	Mounting
[2]NL-1009A	7681	Jumbo C	16-1/2	5-1/2	1200 1500	2250 1800	30 24	105 84	630 504	Conv.
[2]NL-1022A	(6511), 5822A	C	15	4-5/8	1200 1500	1500 1200	20 16	70 56	420 336	Conv.
[2]NL-1051A	(6346), 5551A	B	13	3-1/4	1200 1500	600 480	5 4	22.5 18	135 108	Conv.
NL-1054A	7151	E	22	10-1/8	1200 1500	6000 4800	120 96	340 272	2040 1632	Special
[2]NL-1061	7669	B	11-5/8	3-1/4	1200 1500	600 480	5 4	22.5 18	135 108	Coax.
NL-1064	8205	E	22	10-1/8	1200 1500	6000 4800	120 96	340 272	2040 1632	Coax.
[2]NL-1068	7672	C	12-3/4	4-5/8	1200 1500	1500 1200	20 16	70 56	420 336	Coax.
NL-1069	7998	Jumbo C	15-7/8	5-1/2	1200 1500	2250 1800	30 24	105 84	630 504	Coax.
[2]NL-5553B	(6348), 5553A	D	20-1/2	5-5/8	1200 1500	3000 2400	40 32	140 112	840 672	Conv.
[2]NL-7673	7673	D	17	5-5/8	1200 1500	3000 2400	40 32	140 112	840 672	Coax.

GENERAL INFORMATION:

Cooling — liquid cooled unless other cooling is indicated.

Operating Voltage — 250 to 600 V rms, except where listed.

Warranty — If no warranty is indicated, National's standard N-12 warranty applies.

NATIONAL is and has been for several years, the leader in ignitron development. NATIONAL'S coil construction gives increased cooling efficiency, increased averaging time, permits the use of warmer cooling water and saves water. NATIONAL'S thermostatically protected ignitrons eliminate maintenance problems and loss of production time. NATIONAL'S Hi-Power ignitrons reduce maintenance costs and allow existing equipments to make heavier welds. NATIONAL has the widest line of high voltage switching ignitrons in the industry.

Power Rectifier Service

TYPE	REPLACES*	MAXIMUM RATINGS			MOUNTING	WARRANTY
		Peak Anode Volts	Peak Amps	Average Continuous DC Amps		
NL-5555 NL-5555A	5555 5555A	900 2100	1800 1200	250 150	Conv.	N-12, N-36
NL-6228	6228	20,000	900	150	Special	+

Switching Service

TYPE	REPLACES*	DIMENSION — INCHES		MAXIMUM RATINGS			COOLING	WARRANTY
		Length	Dia.	Peak Anode Volts KV	Peak Current KA	Average Current DC Amps		
NL-1036 NL-1036H	7171	8	2	15	35	0.75	Air or Clamp	+
NL-1037 NL-1037H	—	8	2	20	100	0.75	Air or Clamp	+
NL-1038	—	7	4-1/4	**	100	1.7	Air or Clamp	+
NL-1039	—	8	2	20	100	0.75	Air or Clamp	+
NL-1040	—	7	4-15/16	50	65	0.25	Clamp	+
NL-1059A	—	20	5-1/2	20	100	2.0	Liquid	+
NL-7171 NL-7171H	7171	8	2	15	35	0.75	Air or Clamp	+
NL-7703	7703	8	2	20	100	0.75	Air or Clamp	+
NL-7703H	—	8	2	20	100	0.75	Air or Clamp	+

Continuous Duty Service

TYPE	REPLACES*	SIZE	MAXIMUM DIMENSIONS — INCHES		MAXIMUM RATINGS				Maximum Avg. Time at 500V Seconds	MOUNTING
			Rigid Length	Dia. ★	Maximum Demand KVA	Corres. Current DC Amps	Maximum Current DC Amps	Corres. Demand KVA		
[2]NL-1011A	NL-1011	B	13	3-1/4	600	30.2	56	200	13.5	Conv.
[2]NL-1012A	NL-1012	C	15	4-5/8	1200	75.6	140	400	10.5	Conv.
NL-1013A	NL-1013	D	21	7-1/8	2400	192	355	800	11.0	Conv.
NL-1014A	NL-1014	E	22	10-1/8	4800	486	900	1600	8.9	Special
[2]NL-1016A	NL-1016	Jumbo C	16-1/2	5-1/2	1800	135	220	600	9.6	Conv.
[2]NL-1071	—	B	11-5/8	3-1/4	600	30.2	56	200	13.5	Coax.
[2]NL-1072	—	C	12-3/4	4-5/8	1200	75.6	140	400	10.5	Coax.
NL-1073	—	D	20	7-1/8	2400	192	355	800	11.0	Coax.
NL-1074	—	E	22	10-1/8	4800	486	900	1600	8.9	Coax.
[2]NL-1079	—	Jumbo C	15-7/8	5-1/2	1800	135	220	600	9.6	Coax.

[1]Air Cooled.
[2]Available in plastic coated version.
*These types, offered by other suppliers, can be directly replaced with the listed NATIONAL® TYPE — complete interchangeability.
** Information not released pending completion of life tests.
● Approximately equivalent ½ size A.
★Not including water connection with conventional mounting, cathode mounting plate with coaxial construction, nor mounting stud for the miniature ignitrons.
+Warranty supplied on request.
Coax. Coaxial construction with top cathode mounting plate.
Conv. Conventional cathode bar mounting.
#Operating voltage — 380 to 600 Vrms.

THYRATRONS are grid controlled rectifiers that make possible countless start and stop operations with no maintenance. They function as current and voltage switches that operate silently with no moving parts. The application of a small amount of power to the grid controls many times more anode power accurately and instantaneously.

TYPE	REPLACES*	DESCRIPTION			MAXIMUM DI[illegible]. INCHES	
		HEATER	BASE	CAP	Rigid Lgth.	Bulb Dia.
NL-C3J/L	C3J/L	Filament	Lug	Medium, C1-5	6-3/4	1-5/8
NL-C3J/AL	C3J/AL	Filament	Lug	Medium, C1-5	6-3/4	1-5/8
NL-C3J/AL-Ne	5684, C3J/AL	Filament	Lug	Medium, C1-5	6-3/4	1-5/8
NL-3C23	GL-3C23 WL-3C23 311	Filament	Medium 4-pin bayonet, A4-10	Medium, C1-5	6-1/8	2-1/16
NL-C6J	C6J	Filament	Industrial 4-pin, A4-81	Medium, C1-5	8-3/4	2-1/16
NL-C6J/L	C6J/L	Filament	Lug, A4-90	Medium, C1-5	9-1/4	2-1/16
NL-C6J/P	C6J/F	Filament	Panel mounting	Medium, C1-5	8	2-1/16
NL-C6J/K	GL-6807, C6J/K, GL-5545	Filament	Industrial 4-pin, A4-81	Medium, C1-5	8-3/4	2-1/16
NL-C6J/K-Ne	GL-6807, NL-760 C6J/K, C6J/A	Filament	Industrial 4-pin, A4-81	Medium, C1-5	8-3/4	2-1/16
NL-C6J/KP	C6J/KF, GL6808	Filament	Panel mounting	Medium, C1-5	8	2-1/16
NL-KY21A	——	Filament	Medium 5-pin, A5-11	Medium, C1-5	8	2-1/16
NL-FG-105	FG-105	Indirectly Heated	Jumbo Industrial 4-pin, A4-18	C1-15	11	3
NL-323B	323A, 323B, UE323B	Filament	Medium 5-pin, A5-11	Small, C1-1	6-5/8	2-1/16
NL-393A	393A, GL393A	Filament	Intermediate 7-pin octal, B7-12	Small, C1-1	6-5/8	2-1/16
NL-632B	WL-632A, GL632B WL-632B, 632B	Heater-cathode	Medium 4-pin, A4-71 Medium grid, C1-5, on side of base	Medium, C1-5 Medium grid	8-5/16	2-5/16▶
NL-678	678	Filament	50 Watt, A4-29	Medium, C1-6	11-3/16	2-9/16
NL-710/6011	(C3J), (C3J/A), GL6011 (5632), (5684)	Filament	Medium, 4-pin, A4-10	Medium, C1-5	6-1/4	1-5/8
NL-710L	GL7518 (EL-C3J/L), (EL-C3J/AL)	Filament	Lug	Medium, C1-5	6-5/8	1-5/8
NL-710A	GL-7725	Filament	Medium 4-pin, A4-10	Medium, C1-5	6-1/4	1-5/8
NL-710AL	GL-7726	Filament	Lug	Medium, C1-5	6-5/8	1-5/8
NL-714/7021	——	Filament	Medium 4-pin, A4-10	Medium, C1-5	6-1/8	2-1/16
NL-716	(C1J), (C1K), (C1J/K)	Filament	Medium 4-pin, A4-10	Single ended	4-3/8	1-[illegible]
NL-732	——	Filament	Bracket type mounting	Flexible Leads	19-1/8	3-5/8
NL-734/5544	5544, NL-730	Filament	Industrial 4-pin, A4-81	Medium, C1-5	7-1/2	2-1/16
NL-734L	——	Filament	Lug, A4-90	Medium, C1-5	8-1/4	2-1/16
NL-740/6856	(C4J/A) GL6856	Filament	Industrial 4-pin, A4-81	Medium, C1-5	9-1/2	2-1/16
NL-740P/6857	(C4J/F) GL6857	Filament	Panel mounting	Medium, C1-5	8-5/8	2-1/16
NL-740L/7022	——	Filament	Lug, A4-90	Medium, C1-5	9-1/2	2-1/16
NL-760	(C6J), (5685), (GL6807), GL6858	Filament	Jumbo industrial 4-pin, A4-18	Medium, C1-5	9-1/2	2-9/16
NL-760P	(C6J/A), (5545) (C6J/F), (C6J/AF) (GL6808), GL6859	Filament	Panel mounting base	Medium, C1-5	8-3/4	2-9/16
NL-760L	(C6J/L), (C6J/KL) GL6860 (GL6809)	Filament	Lug base, A4-90	Medium, C1-5	10	2-9/16
NL-770P	——	Filament	Panel mounting	Flexible Leads	9-1/2	2-9/16
NL-770L	——	Filament	Lug, A4-90	Flexible Leads	10-3/4	2-9/16
NL-780	C16J/A	Filament	Panel Mounting	Flexible Leads	10-1/2	2-9/16
NL-5557/FG17/715	FG-17, WL-17, 976 309, TT-17 WT272	Filament	Medium 4-pin, A4-10	Medium, C1-5	6-1/8	2-1/16
NL-5559/FG-57	FG-57, 5559, GL5559/FG57, WL5559/FG57	Heater-cathode	Medium 4-pin, A4-10	Medium, C1-5	7-1/4	2-1/16
NL-5560/FG-95	FG-95, 5560 GL5560, WL 5560	Heater-cathode	Medium 4-pin, A4-71 C1-5, on side of base	Medium, C1-5	7-15/16	2-5/16▶
NL-5563A	5563A	Filament	50 Watt, A4-29	Medium, C1-5	10-17/32	2-9/16
NL-5632/C3J	5632, C3J	Filament	Medium 4-pin, A4-10	Medium, C1-5	6	1-5/8
NL-5665/C16J	EL-C16J, 5665	Filament	Panel mounting	Flexible leads	10-1/2	2-9/16
NL-5684/C3J/A	5684, C3J/A	Filament	Medium 4-pin, A4-10	Medium, C1-5	6	1-5/8
NL-5684-Ne	C3J, C3J/A	Filament	Medium 4-pin, A4-10	Medium, C1-5	6	1-5/8
NL-5684A-Ne	C3J, 6011 NL-710	Filament	Medium 4-pin, A4-10	Medium, C1-5	6	1-5/8
NL-6014/C1K	C1J, C1J/K, C1K, 6014	Filament	Medium 4-pin, A4-10	Single Ended	4-5/16	1-9/16
NL-6989/C6J/KL	C6J/KL, GL6809	Filament	Lug, A4-90	Medium, C1-5	9-1/4	2[illegible]
NL-6989-Ne	6989, 6807, 7298 C6J/KL, C6J/AL	Filament	Lug, A4-90	Medium, C1-5	9-1/4	2-1/16
NL-7556A-Ne	C3J/L, 7556A, C3J/AL 7518, NL-710L	Filament	Lug	Medium, C1-5	6-3/4	1-5/8

* These types, offered by other suppliers, can be directly replaced with the listed NATIONAL® POWER TUBE — completely interchangeable. Tubes listed in parenthesis can

▶ Does not include grid cap.

NATIONAL® Thyratrons are available in a variety of sizes and ratings for every application. NATIONAL® combination gas and mercury vapor thyratrons combine the quick starting of gas tubes with the long life of mercury tubes to give the best possible thyratrons for industrial applications. For higher voltage application, mercury vapor tubes with the same current ratings are available. Suffix leters P and L denote panel mounting and lug base types, respectively.

FILAMENT		GAS FILLING	Number of Electrodes	MAXIMUM RATINGS					WARRANTY	TYPE
Volts	Amps			Peak Inverse Volts	Peak Forward Volts	Peak Anode Amps	Average Anode Amps	Surge Amps		
2.5	9	Xenon	3	1250	900	30	2.5	300	N-24-1	NL-C3J/L
2.5	9	Xenon	3	1250	1000	30	2.5	300	N-24-1	NL-C3J/AL
2.5	9	Xenon	3	1250	1000	30	2.5	300	N-24-1	NL-C3J/AL-Ne
2.5	7	Gas & Merc.	3	1250	1250	6	1.5	120	N-24	NL-3C23
2.5	21	Xenon	3	1250	750	80	6.4	770	N-3000	NL-C6J
2.5	21	Xenon	3	1250	750	80	6.4	770	N-24-1	NL-C6J/L
2.5	21	Xenon	3	1250	750	80	6.4	770	N-24-1	NL-C6J/P
2.5	21	Xenon	3	1250	1000	80	6.4	770	N-3000	NL-C6J/K
2.5	21	Xenon	3	1250	1000	80	6.4	770	N-24-1	NL-C6J/K-Ne
2.5	21	Xenon	3	1250	1000	80	6.4	770	N-24-1	NL-C6J/KP
2.5	10	Merc.	3	11,000	5500	3	0.75	100	N-1000	NL-KY21A
5.0	10	Merc.	4	10,000	10,000	77	6.4	400	N-12	NL-FG-105
2.5	7	Gas & Merc.	3	1250	1250	6	1.5	120	N-12	NL-323B
2.5	7	Gas & Merc.	3	1250	1250	6	1.5	120	N-12	NL-393A
5.0	4.7	Merc.	4	1500	1500	30	2.5	150	N-12	NL-632B
5.0	7.5	Merc.	3	15,000	15,000	6	1.6	50	N-1000	NL-678
2.5	9	Gas & Merc.	3	1500	1500	30	2.5	250	N-12	NL-710/6011
2.5	9	Gas & Merc.	3	1500	1500	30	2.5	250	N-24	NL-710L
2.5	9	Gas & Merc.	3	3500	3500	30	2.5	250	N-12	NL-710A
2.5	9	Gas & Merc.	3	3500	3500	30	2.5	250	N-12	NL-710AL
2.5	5	Gas & Merc.	3	1250	1250	3	1	50	N-24	NL-714/7021
2.[illegible]	6.3	Gas & Merc.	3	1250	1250	8	1	80	N-24	NL-716
2.5	55	Gas & Merc.	3	1500	1500	160	30	2500	N-12	NL-732
2.5	11.5	Xenon	3	1500	1500	40	3.2	560	N-24-1	NL-734/5544
2.5	11.5	Xenon	3	1500	1500	40	3.2	560	N-24-1	NL-734L
2.5	16	Gas & Merc.	3	1500	1500	30	4			NL-740/6856
2.5	16	Gas & Merc.	3	1500	1500	50	2.5	400	N-24	NL-740P/6857
2.5	16	Gas & Merc.	3	1500	1500					NL-740L/7022
2.5	21	Gas & Merc.	3	1500	1500	77	6.4	770	N-12	NL-760
2.5	21	Gas & Merc.	3	1500	1500	77	6.4	770	N-24	NL-760P
2.5	21	Gas & Merc.	3	1500	1500	77	6.4	770	N-24	NL-760L
2.5	25	Gas & Merc.	3	1500	1500	120	10	1000	N-12	NL-770P
2.5	25	Gas & Merc.	3	1500	1500	120	10	1000	N-12	NL-770L
2.5	31	Xenon	3	1700	1700	100 160	18 16	1000	N-24-1	NL-780
2.5	5	Merc.	3	5000	2500	2	.5	50	N-12	NL-5557/FG17/715
5.0	4.5	Merc.	3	1000	1000	15	2.5	200	N-12	NL-5559/FG-57
5.0	4.5	Merc.	4	1000	1000	15	2.5	200	N-12	NL-5560/FG-95
5.0	7.5	Merc.	3	20,000	20,000	11.5	2.5	70	N-1000	NL-5563A
2.5	9	Xenon	3	1250	900	30	2.5	300	N-3000	NL-5632/C3J
2.5	31	Xenon	3	1250	1000	100 160	18 16	1000	N-24-1	NL-5665/C16J
2.5	9	Xenon	3	1250	1000	30	2.5	300	N-3000	NL-5684/C3J/A
2.5	9	Xenon & Neon	3	1250	1000	30	2.5	300	N-24-1	NL-5684-Ne
2.5	9	Xenon & Neon	3	1500	1500	30	2.5	300	N-24-1	NL-5684A-Ne
2.5	6.3	Xenon	3	1250	1000	8	1	77	N-3000	NL-6014/C1K
[illegible]	21	Xenon	3	1250	1000	80	6.4	770	N-24-1	NL-6989/C6J/KL
2.5	21	Xenon & Neon	3	1250	1000	80	6.4	770	N-24-1	NL-6989-Ne
2.5	9	Xenon & Neon	3	1500	1500	30	2.5	300	N-24-1	NL-7556A-Ne

be replaced with NATIONAL® type except in abnormal applications, especially those involving air temperatures above 140°F, where it is desirable to check ratings.

RECTIFIERS are electronic valves and are the principal means used today for the conversion of alternating current to direct current. Recent refinements and developments have made rectifier tubes available that are especially suited for every need in the rapidly expanding industrial electronic control field.

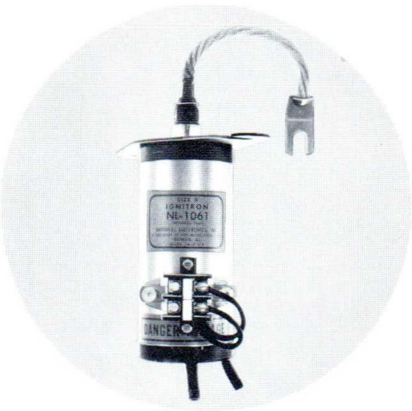
NATIONAL® Rectifiers are especially designed for industrial applications. They are available in a variety of voltage and current ratings to supply all types of requirements. The sturdy construction, increased efficiency, low maintenance, and reliability of NATIONAL® rectifier tubes have made them one of the leaders in the industrial electronics field. Suffix letters P and L denote panel mounting and lug base types, respectively. All types are 2.5 volts filament unless noted otherwise.

TYPE	REPLACES*	MAX. DIM. INCHES		BASE	CAP	FIL. AMPS	GAS FILLING	MAXIMUM RATINGS			Warranty
		Rigid Lgth.	Bulb Dia.					Peak Inverse Volts	Peak Anode Amps	Average Anode Amps	
NL-RX21A	——	8	2-1/16	A5-11	C1-5	10	Merc.	11,000	3	0.75	N-1000
NL-575A	575A	11-1/8	2-9/16	A4-29	C1-5	10†	Merc.	15,000	10	2.5	N-1000
NL-604 NL-604L	(EL-3C) (EL-3CL)	7-1/2 7-1/2	2-1/16 2-1/16	A4-81 A4-90	——	11.5	Gas & Merc.	900	10	2.5	N-24
NL-606 NL-606L	(EL-6C) (EL-6CL)	8 8-5/8	2-9/16 2-9/16	A4-18 A4-90	——	17	Gas & Merc.	900	25.6	6.4	N-12 N-24
NL-610/7723	——	5-1/2	1-5/8	A4-10	C1-5	9	Xenon	920	30	2.5	N-3000
NL-615	CE-213	6-3/8	2-1/16	A4-10	C1-5	7	Merc.	2000	10	2.5	N-24
NL-616	——	6-1/4	1-5/8	A4-10	C1-5	9	Gas & Merc.	1250	30	2.5	N-12
NL-617	CE-205	8-1/4	2-1/16	Mogul Screw	C1-5	11.5 ♮	Merc.	1000	20	5.0	N-12
NL-619	CE-206	7	2-1/16	G2-3	C1-5	11.5 ♮	Merc.	300	20	6.0	N-12
NL-623	CE-203 CE-215	8-3/4	3-13/16	Mogul Screw	Flex Lead	20	Merc.	500	45	15	N-12
NL-625	CE-202 & B	11-3/4	3-13/16	Mogul Screw	Flex Lead	20	Merc.	900	45	15	N-12
NL-627	CE-207 RX-212	12	3-13/16	Mogul Screw	C1-5	26	Merc.	1000	120	20	N-3000
NL-635/7019 NL-635L/7020 NL-635P/6930	(EL-6B) (EL-6B/L) (EL-6F)	9-1/2 9-1/2 8-5/8	2-1/16 2-1/16 2-1/16	A4-81 A4-90 Panel	C1-5	18	Gas & Merc.	1000	77	6.4	N-12 N-24 N-24
NL-643	——	10	2-9/16	Mogul Screw	Flex Lead	23	Merc.	700	90	15	N-12
NL-649/5834	249R&S, 5834	5-7/16	1-9/16	A4-10	——	7	Merc.	900	10	2.0	N-12
NL-653/5835	BR-3, 5835	5-3/4	2-1/16	A4-10	——	9.5	Merc.	900	12	3.0	N-12
NL-660 NL-660L/7786 NL-660P	EL-6B EL-6B/L EL-6F	8-3/4 9-1/4 8	2-1/16 2-1/16 2-1/16	A4-81 A4-90 Panel	C1-5	21	Xenon	920	80	6.4	N-12
NL-664L NL-664P	—— ——	10-3/4 9-7/8	2-1/16 2-1/16	A4-90 Panel	Flex	25	Gas & Merc.	1000	120	10	N-12
NL-673	673	11-7/16	2-9/16	A4-18	C1-5	10†	Merc.	15,000	10	2.5	N-1000
NL-869B	869B	14-1/4	3	A3-20	C1-9	19†	Merc.	20,000	20	5.0	N-1000
NL-5558/FG32	5558, FG-32	7	1-9/16	A4-10	——	4.5†	Merc.	2000	15	2.5	N-12
NL-6894 NL-6895	6894 6895	10-17/32 10-13/32	2-9/16 2-9/16	A4-29 A4-18	C1-5	10†	Merc.	20,000	11.5	2.5	N-1
NL-7723-Ne	NL-610, 3B	5-1/2	1-5/8	A4-10	C1-5	9	Xenon & Neon	920	30	2.5	N-24-1
NL-7786-Ne	NL-660L	9-1/4	2-1/16	A4-90	C1-5	21	Xenon & Neon	920	80	6.4	N-24-1

*These types, offered by other suppliers, can be directly replaced with the listed NATIONAL® POWER TUBE — complete interchangeability. Tubes listed in parenthesis can be replaced with NATIONAL® type except in abnormal applications, especially those involving air temperatures above 140°F, where it is desirable to check ratings.

♮Filament voltage is 2.0 volts.

†Filament voltage is 5.0 volts.



TUBE ACCESSORIES

The following tube accessories for use with NATIONAL® industrial tubes are available from National Electronics, Inc.

THERMOSTAT KITS — include thermostat and mounting clamp with spring loaded fasteners. Spencer-Klixon thermostats for both water saving and tube protection — Single pole with one pair of contacts. Contact ratings — 3 amps at 125V, 1.5 amps at 250V, .75 amps at 440V and .50 amps at 600V. Maximum potential — Shell to contacts — 600V dc. Rubber covered flexible leads with spade terminals.

TYPE	USE	CONTACTS	TEMPERATURE OPEN	TEMPERATURE CLOSE	LEAD LENGTH INCHES	TERMINAL BLOCK
C4391N7-51	Water Saver	NO	86° F	96° F	3-1/2	Yes
C4391N7-52	Protection	NC	125	105	3-1/2	Yes
C4391N7-58	Water Saver	NO	86	96	36	No
C4391N7-59	Protection	NC	125	105	36	No
C4391N7-299	Protection	NC	161	141	3-1/2	Yes
C4391N7-345	Water Saver	NO	141	161	3-1/2	Yes

LUG BASE SOCKET — available for use with L type tubes. Mounts through the panel. Either behind or front panel wiring. Provided with socket cover to eliminate exposed terminals.

TYPE NO.	USED WITH
LBTS-1, LBTS-2	Rectifiers and Thyratrons with lug bases.

QUICK CHANGE IGNITRON WATER CONNECTORS — brass fittings available for making quick change water hose connections to ignitrons. A connection consists of one socket and one plug.

TYPE NO.	DESCRIPTION	USED WITH TUBE TYPE
B1HK	Brass Socket	Sizes B & C
B1K11	Brass Plug	Sizes B & C
B2HK	Brass Socket	Size D
B2K16	Brass Plug	Size D

OTHER PUBLICATIONS AVAILABLE:

National® Industrial Tube Interchangeability, SB-2D

National® Life Indicating Tubes, SB-12

Operation and Maintenance Hints for Ignitrons, Thyratrons, and Rectifiers, SB-18

Ignitron Selection Chart, SB-21

National® Readout Tubes, SB-26

Readout Tube Interchangeability, SB-27

WARRANTIES

NATIONAL tubes carry the longest warranties in the industry.

Preferred Thyratrons and Rectifiers are guaranteed for 2 years. These tubes are outstandingly reliable and very conservatively designed. Sockets are available for these types that are highly reliable at the currents involved.

All NATIONAL electronic tubes are designed and built to give the longest life possible under the conditions imposed by the application.

N-24 WARRANTY — 2 YEARS

Preferred NATIONAL Thyratrons and Rectifiers are warranted for 2 YEARS against defects in design, material, and workmanship when used within published ratings. If such defects appear within 2 YEARS after the tube is placed in service, a pro-rata adjustment will be made, based upon the difference between the elapsed life in months at failure and 2 years. A fraction of a month, consisting of sixteen days or more, will be considered a full month of life. A period of fifteen days or less will be deducted from the tube life.

If defects appear within one year after the tube is placed in service, free replacement will be made.

Once a tube has been installed in regular service its life will be considered continuous.

No adjustment will be made if the tube life exceeds 2 years. This warranty expires 2½ years after date of sale to ultimate user and 3 years after date of shipment by manufacturer.

N-24-1 WARRANTY — 2 YEARS

Certain specified NATIONAL tubes are warranted for 2 YEARS against defects in design, material, and workmanship when used within published ratings. If such defects appear within 2 YEARS after the tube is placed in service, a pro-rata adjustment will be made, based upon the difference between the elapsed life in months at failure and 2 years. A fraction of a month, consisting of sixteen days or more, will be considered a full month of life. A period of fifteen days will be deducted from the tube life.

Once a tube has been installed in regular service its life will be considered continuous.

No adjustment will be made if the tube life exceeds 2 years. This warranty expires 2½ years after date of sale to ultimate user and 3 years after date of shipment by manufacturer.

N-12 WARRANTY — 1 YEAR

Certain specified NATIONAL Industrial Tubes are warranted for 1 YEAR against defects in design, material, and workmanship when used within published ratings. If such defects appear within 1 YEAR after the tube is placed in service, a pro-rata adjustment will be made, based upon the difference between the elapsed life in months at failure and one year. A fraction of a month, consisting of sixteen days or more, will be considered a full month of life. A period of fifteen days or less will be deducted from the tube life.

Once a tube has been installed in regular service its life will be considered continuous.

No adjustment will be made if the tube life exceeds 1 year. This warranty expires 1½ years after date of sale to ultimate user and 2 years after date of shipment by manufacturer.

N-1 WARRANTY — 1 MONTH

Certain specified NATIONAL Industrial Tubes are warranted for 1 MONTH against defects in design, material, and workmanship when used within published ratings. If such defects appear within one month after the tube is placed in service, free replacement will be made.

Once a tube has been installed in regular service its life will be considered continuous.

No adjustment will be made if the tube life exceeds 1 month. This warranty expires 1 year after date of shipment by manufacturer.

N-3000 WARRANTY — 3000 HOURS

Certain specified NATIONAL Industrial Tubes are warranted to be free from defects in design, material, and workmanship for a useful life in excess of 3000 HOURS when used within published ratings. If such defects appear before 3000 hours of use, a pro-rata adjustment will be made, based upon the difference between the tube life in hours at failure and 3000 hours.

The tube life in hours is the actual total time the tube has been used.

No adjustment will be made if the tube life exceeds 3000 hours. This warranty expires 1½ years after date of sale to ultimate user and 2 years after date of shipment by manufacturer.

N-1000 WARRANTY — 1000 HOURS

Certain specified NATIONAL tubes are warranted to be free from defects in design, material, and workmanship for a useful life in excess of 1000 HOURS when used within published ratings. If such defects appear before 1000 hours of use, a pro-rata adjustment will be made, based upon the difference between the tube life in hours at failure and 1000 hours.

The tube life in hours is the actual time the tube has been used.

No adjustment will be made if the tube life exceeds 1000 hours. This warranty expires 1 year after sale to the ultimate user and 1½ years after date of shipment by manufacturer.

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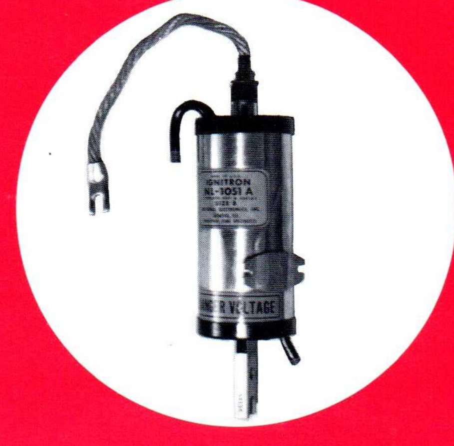
NATIONAL ELECTRONICS INDUSTRIAL TUBES



IGNITRONS
THYRATRONS
RECTIFIERS
THYRISTOR STACKS

NATIONAL ELECTRONICS
a varian division
GENEVA, ILLINOIS 60134
TELEPHONE 312 232-4300
TWX 910 237-1685

IGNITRONS are ignitor fired mercury pool rectifiers with high peak current capacity. Their ability to switch high currents at high speed makes it possible to control both the duration and amplitude of current required for consistent and accurate welding. They combine the high speed switching and high current capacity required for high voltage capacitor bank switching and crowbar operation.

Resistance Welder Service

TYPE	REPLACES	SIZE	MAXIMUM DIMENSION — INCHES		MAXIMUM RATINGS				Maximum Avg. Time at 500V Seconds	Mounting
			Rigid Length	Dia.*	Maximum Demand KVA	Corres. Current DC Amps	Maximum Current DC Amps	Corres. Demand KVA		
[1]NL-1001	——	•	9-3/16	2-5/8	150	4.9	9.0	50	14	Special
[1]NL-1005A	NL-1005	B	15-1/2	5-5/8	600	30.2	56	200	9	Conv.
[2]NL-1009A	7681	Jumbo C	16-1/2	5-1/2	1800	135	220	600	9.6	Conv.
NL-1031	——	B	6	3-9/16	600#	30.2	56	200#	9	Stud
NL-1032	——	C	8-7/8	3-9/16	1200#	75.6	140	400#	7	Stud
[2]NL-1051A	(6346), 5551A	B	13	3-1/4	600	30.2	56	200	13.5	Conv.
[2]NL-1052A	(6347), 5552A	C	15	4-5/8	1200	75.6	140	400	10.5	Conv.
NL-1053A	NL-1053	D-6000	21	7-1/8	3000	224	400	1000	11.0	Conv.
NL-1054A	7151, NL-1054	E	22	10-1/8	4800	486	900	1600	8.9	Special
[2]NL-1061	7669	B	11-5/8	3-1/4	600	30.2	56	200	13.5	Coax.
[2]NL-1062	7671	C	12-3/4	4-5/8	1200	75.6	140	400	10.5	Coax.
NL-1063	——	D-6000	20	7-1/8	3000	224	400	1000	11.0	Coax.
NL-1064	8205	E	22	10-1/8	4800	486	900	1600	8.9	Coax.
[2]NL-1069	7998	Jumbo C	15-7/8	5-1/2	1800	135	220	600	9.6	Coax.
[2]NL-1081	——	B-2000	13	3-1/4	1000	43.2	75	200	13.5	Conv.
[2]NL-1082	——	C-4000	15	4-5/8	2000	108	150	380	10.5	Conv.
[2]NL-1091	——	B-2000	11-5/8	3-1/4	1000	43.2	75	200	13.5	Coax.
[2]NL-1092	——	C-4000	12-3/4	4-5/8	2000	108	150	380	10.5	Coax.
NL-5550	5550	A	9-7/8	2.140	300	12.1	22.4	100	9.2	Clamp
[2]NL-5551A	(6346) 5551A	B	13	2-3/4	600	30.2	56	200	7.5	Conv.
[2]NL-5552A	5552A	C	14	4-1/4	1200	75.6	140	400	5.8	Conv.
[2]NL-5553B	(6348), 5553A	D	20-1/2	5-5/8	2400	192	355	800	5.5	Conv.
[2]NL-7669	7669	B	11-5/8	2-3/4	600	30.2	56	200	7.5	Coax.
[2]NL-7671	7671	C	13	4-1/4	1200	75.6	140	400	5.8	Coax.
[2]NL-7673	7673	D	17	5-5/8	2400	192	355	800	5.5	Coax.

Frequency-Changer Welder Service

TYPE	REPLACES	SIZE	MAXIMUM DIMENSION — INCHES		MAXIMUM RATED CURRENT				Corres. Peak Amps	Mounting
			Rigid Length	Dia.*	Inverse Anode Volts	Max. Peak Amps	Corres. DC Amps	Max. DC Amps		
[2]NL-1009A	7681	Jumbo C	16-1/2	5-1/2	1200 1500	2250 1800	30 24	105 84	630 504	Conv.
[2]NL-1022A	(6511), 5822A	C	15	4-5/8	1200 1500	1500 1200	20 16	70 56	420 336	Conv.
[2]NL-1051A	(6346), 5551A	B	13	3-1/4	1200 1500	600 480	5 4	22.5 18	135 108	Conv.
NL-1054A	7151	E	22	10-1/8	1200 1500	6000 4800	120 96	340 272	2040 1632	Special
[2]NL-1061	7669	B	11-5/8	3-1/4	1200 1500	600 480	5 4	22.5 18	135 108	Coax.
NL-1064	8205	E	22	10-1/8	1200 1500	6000 4800	120 96	340 272	2040 1632	Coax.
[2]NL-1068	7672	C	12-3/4	4-5/8	1200 1500	1500 1200	20 16	70 56	420 336	Coax.
NL-1069	7998	Jumbo C	15-7/8	5-1/2	1200 1500	2250 1800	30 24	105 84	630 504	Coax.
[2]NL-5551A	(6346), 5551A	B	13	2-3/4	1200	600	5	22.5	135	Conv.
[2]NL-5553B	(6348), 5553A	D	20-1/2	5-5/8	1200 1500	3000 2400	40 32	140 112	840 672	Conv.
[2]NL-7669	7669	B	11-5/8	2-3/4	1200	600	5	22.5	135	Coax.
[2]NL-7673	7673	D	17	5-5/8	1200 1500	3000 2400	40 32	140 112	840 672	Coax.

GENERAL INFORMATION:

Cooling — liquid cooled unless other cooling is indicated.

Operating Voltage — 250 to 600 V rms, except where listed.

Warranty — If no warranty is indicated, National's standard N-12 warranty applies.

NATIONAL® is and has been for several years, the leader in ignitron development. NATIONAL'S coil construction gives increased cooling efficiency, increased averaging time, permits the use of warmer cooling water and saves water. NATIONAL'S thermostatically protected ignitrons eliminate maintenance problems and loss of production time. NATIONAL'S Hi-Power ignitrons reduce maintenance costs and allow existing equipments to make heavier welds. NATIONAL has the widest line of high voltage switching ignitrons in the industry.

Power Rectifier Service

TYPE	REPLACES*	MAXIMUM RATINGS			MOUNTING	WARRANTY
		Peak Anode Volts	Peak Amps	Average Continuous DC Amps		
NL-5555 NL-5555A	5555 5555A	900 2100	1800 1200	250 150	Conv.	N-12, N-36
NL-6228	6228	20,000	900	150	Special	+

Switching Service

TYPE	REPLACES*	DIMENSION — INCHES		MAXIMUM RATINGS			COOLING	WARRANTY
		Length	Dia.	Peak Anode Volts KV	Peak Current KA	Average Current DC Amps		
NL-1036 NL-1036H	7171	8	2	15	35	0.75	Air or Clamp	+
NL-1037 NL-1037H	—	8	2	20	100	0.75	Air or Clamp	+
NL-1038	—	7	4-1/4	**	100	1.7	Air or Clamp	+
NL-1039	—	8	2	20	100	0.75	Air or Clamp	+
NL-1040	—	7	4-15/16	50	65	0.25	Clamp	+
NL-1059A	—	20	5-1/2	20	100	2.0	Liquid	+
NL-7171 NL-7171H	7171	8	2	15	35	0.75	Air or Clamp	+
NL-7703	7703	8	2	20	100	0.75	Air or Clamp	+
NL-7703H	—	8	2	20	100	0.75	Air or Clamp	+

Continuous Duty Service

TYPE	REPLACES *	SIZE	MAXIMUM DIMENSIONS — INCHES		MAXIMUM RATINGS				Maximum Avg. Time at 500V Seconds	MOUNTING
			Rigid Length	Dia. ★	Maximum Demand KVA	Corres. Current DC Amps	Maximum Current DC Amps	Corres. Demand KVA		
²NL-1011A	NL-1011	B	13	3-1/4	600	30.2	56	200	13.5	Conv.
²NL-1012A	NL-1012	C	15	4-5/8	1200	75.6	140	400	10.5	Conv.
NL-1013A	NL-1013	D	21	7-1/8	2400	192	355	800	11.0	Conv.
NL-1014A	NL-1014	E	22	10-1/8	4800	486	900	1600	8.9	Special
²NL-1016A	NL-1016	Jumbo C	16-1/2	5-1/2	1800	135	220	600	9.6	Conv.
²NL-1071	—	B	11-5/8	3-1/4	600	30.2	56	200	13.5	Coax.
²NL-1072	—	C	12-3/4	4-5/8	1200	75.6	140	400	10.5	Coax.
NL-1073	—	D	20	7-1/8	2400	192	355	800	11.0	Coax.
NL-1074	—	E	22	10-1/8	4800	486	900	1600	8.9	Coax.
²NL-1079	—	Jumbo C	15-7/8	5-1/2	1800	135	220	600	9.6	Coax.

¹Air Cooled.
²Available in plastic coated version.
*These types, offered by other suppliers, can be directly replaced with the listed NATIONAL® TYPE — complete interchangeability.
** Information not released pending completion of life tests.
● Approximately equivalent ½ size A.
★Not including water connection with conventional mounting, cathode mounting plate with coaxial construction, nor mounting stud for the miniature ignitrons.
+ Warranty supplied on request.
Coax. Coaxial construction with top cathode mounting plate.
Conv. Conventional cathode bar mounting.
#Operating voltage — 380 to 600 Vrms.

THYRATRONS are grid controlled rectifiers that make possible countless start and stop operations with no maintenance. They function as current and voltage switches that operate silently with no moving parts. The application of a small amount of power to the grid controls many times more anode power accurately and instantaneously.

TYPE	REPLACES*	DESCRIPTION			MAXIMUM DIMENS. INCHES	
		HEATER	BASE	CAP	Rigid Lgth.	Bulb Dia.
NL-C3J/L	C3J/L	Filament	Lug	Medium, C1-5	6-3/4	1-5/8
NL-C3J/AL	C3J/AL	Filament	Lug	Medium, C1-5	6-3/4	1-5/8
NL-C3J/AL-Ne	5684, C3J/AL	Filament	Lug	Medium, C1-5	6-3/4	1-5/8
NL-3C23	GL-3C23 WL-3C23 311	Filament	Medium 4-pin bayonet, A4-10	Medium, C1-5	6-1/8	2-1/16
NL-C6H-1	EL-C6H-1, GL-6807	Filament	Ind 4PIN, A4-81	Medium, C1-5	8-3/4	2-1/16
NL-C6H-2	EL-C6H-2, GL-6808	Filament	Panel Mounting	Medium, C1-5	8	2-1/16
NL-C6H-3	EL-C6H-3, GL-6809	Filament	Lug, A4-90	Medium, C1-5	9-1/4	2-1/16
NL-C6J	C6J	Filament	Industrial 4-pin, A4-81	Medium, C1-5	8-3/4	2-1/16
NL-C6J/L	C6J/L	Filament	Lug, A4-90	Medium, C1-5	9-1/4	2-1/16
NL-C6J/P	—	Filament	Panel mounting	Medium, C1-5	8	2-1/16
NL-C6J/K	GL-6807, C6J/K, GL-5545	Filament	Industrial 4-pin, A4-81	Medium, C1-5	8-3/4	2-1/16
NL-C6J/K-Ne	GL-6807, NL-760 C6J/K, C6J/A	Filament	Industrial 4-pin, A4-81	Medium, C1-5	8-3/4	2-1/16
NL-C6J/KP	C6J/KF, GL6808, C6J/F	Filament	Panel mounting	Medium, C1-5	8	2-1/16
NL-KY21A	—	Filament	Medium 5-pin, A5-11	Medium, C1-5	8	2-1/16
NL-FG-105	FG-105	Indirectly Heated	Jumbo Industrial 4-pin, A4-18	C1-15	11	3
NL-323B	323A, 323B, UE323B	Filament	Medium 5-pin, A5-11	Small, C1-1	6-5/8	2-1/16
NL-393A	393A, GL393A	Filament	Intermediate 7-pin octal, B7-12	Small, C1-1	6-5/8	2-1/16
NL-632B	WL-632A, GL632B WL-632B, 632B	Heater-cathode	Medium 4-pin, A4-71 Medium grid, C1-5, on side of base	Medium, C1-5 Medium grid	8-5/16	2-5/16▶
NL-678	678	**Filament**	**50 Watt, A4-29**	**Medium, C1-6**	**11-3/16**	**2-9/16**
NL-710/6011	(C3J), (C3J/A), GL6011 (5632), (5684)	Filament	Medium, 4-pin, A4-10	Medium, C1-5	6-1/4	1-5/8
NL-710L	GL7518 (EL-C3J/L), (EL-C3J/AL)	Filament	Lug	Medium, C1-5	6-5/8	1-5/8
NL-710A	GL-7725	Filament	Medium 4-pin, A4-10	Medium, C1-5	6-1/4	1-5/8
NL-710AL	GL-7726	Filament	Lug	Medium, C1-5	6-5/8	1-5/8
NL-714/7021	—	Filament	Medium 4-pin, A4-10	Medium, C1-5	6-1/8	2-1/16
NL-716	(C1J), (C1K), (C1J/K)	Filament	Medium 4-pin, A4-10	Single ended	4-3/8	1-9/16
NL-732	—	Filament	Bracket type mounting	Flexible Leads	19-1/8	3-5/8
NL-734/5544	5544, NL-730	Filament	Industrial 4-pin, A4-81	Medium, C1-5	7-1/2	2-1/16
NL-734L	—	Filament	Lug, A4-90	Medium, C1-5	8-1/4	2-1/16
NL-740/6856	(C4J/A) GL6856	Filament	Industrial 4-pin, A4-81	Medium, C1-5	9-1/2	2-1/16
NL-740P/6857	(C4J/F) GL6857	Filament	Panel mounting	Medium, C1-5	8-5/8	2-1/16
NL-740L/7022	—	Filament	Lug, A4-90	Medium, C1-5	9-1/2	2-1/16
NL-760	(C6J), (5685), (GL6807), GL6858	Filament	Jumbo industrial 4-pin, A4-18	Medium, C1-5	9-1/2	2-9/16
NL-760P	(C6J/A), (5545) (C6J/F), (C6J/AF) (GL6808), GL6859	Filament	Panel mounting base	Medium, C1-5	8-3/4	2-9/16
NL-760L	(C6J/L), (C6J/KL) GL6860 (GL6809)	Filament	Lug base, A4-90	Medium, C1-5	10	2-9/16
NL-770P	—	Filament	Panel mounting	Flexible Leads	9-1/2	2-9/16
NL-770L	—	Filament	Lug, A4-90	Flexible Leads	10-3/4	2-9/16
NL-780	C16J/A	Filament	Panel Mounting	Flexible Leads	10-1/2	2-9/16
NL-5557/FG17/715	FG-17, WL-17, 976 309, TT-17 WT272	Filament	Medium 4-pin, A4-10	Medium, C1-5	6-1/8	2-1/16
NL-5559/FG-57	FG-57, 5559, GL5559/FG57, WL5559/FG57	Heater-cathode	Medium 4-pin, A4-10	Medium, C1-5	7-1/4	2-1/16
NL-5560/FG-95	FG-95, 5560 GL5560, WL 5560	Heater-cathode	Medium 4-pin, A4-71 C1-5, on side of base	Medium, C1-5	7-15/16	2-5/16▶
NL-5563A	5563A	**Filament**	**50 Watt, A4-29**	**Medium, C1-5**	**10-17/32**	**2-9/16**
NL-5632/C3J	5632, C3J	Filament	Medium 4-pin, A4-10	Medium, C1-5	6	1-5/8
NL-5665/C16J	EL-C16J, 5665	Filament	Panel mounting	Flexible leads	10-1/2	2-9/16
NL-5684/C3J/A	5684, C3J/A	Filament	Medium 4-pin, A4-10	Medium, C1-5	6	1-5/8
NL-5684-Ne	C3J, C3J/A	Filament	Medium 4-pin, A4-10	Medium, C1-5	6	1-5/8
NL-5684A-Ne	C3J, 6011 NL-710	Filament	Medium 4-pin, A4-10	Medium, C1-5	6	1-5/8
NL-6014/C1K	C1J, C1J/K, C1K, 6014	Filament	Medium 4-pin, A4-10	Single Ended	4-5/16	1-9/16
NL-6989/C6J/KL	C6J/KL, GL6809	Filament	Lug, A4-90	Medium, C1-5	9-1/4	2-1/16
NL-6989-Ne	6989, 6807, 7298 C6J/KL, C6J/AL	Filament	Lug, A4-90	Medium, C1-5	9-1/4	2-1/16
NL-7556A-Ne	C3J/L, 7556A, C3J/AL 7518, NL-710L	Filament	Lug	Medium, C1-5	6-3/4	1-5/8

* These types, offered by other suppliers, can be directly replaced with the listed NATIONAL® POWER TUBE – completely interchangeable. Tubes listed in parenthesis can

▶ Does not include grid cap.

NATIONAL® Thyratrons are available in a variety of sizes and ratings for every application. NATIONAL® combination gas and mercury vapor thyratrons combine the quick starting of gas tubes with the long life of mercury tubes to give the best possible thyratrons for industrial applications. For higher voltage application, mercury vapor tubes with the same current ratings are available. Suffix leters P and L denote panel mounting and lug base types, respectively.

FILAMENT		GAS FILLING	Number of Electrodes	MAXIMUM RATINGS					WARRANTY	TYPE
Volts	Amps			Peak Inverse Volts	Peak Forward Volts	Peak Anode Amps	Average Anode Amps	Surge Amps		
2.5	9	Xenon	3	1250	900	30	2.5	300	N-24-1	NL-C3J/L
2.5	9	Xenon	3	1250	1000	30	2.5	300	N-24-1	NL-C3J/AL
2.5	9	Xenon	3	1250	1000	30	2.5	300	N-24-1	NL-C3J/AL-Ne
2.5	7	Gas & Merc.	3	1250	1250	6	1.5	120	N-24	NL-3C23
2.5	21	Xenon	3	1700	1700	80	6.4	770	N-24-1	NL-C6H-1
2.5	21	Xenon	3	1700	1700	80	6.4	770	N-24-1	NL-C6H-2
2.5	21	Xenon	3	1700	1700	80	6.4	770	N-24-1	NL-C6H-3
2.5	21	Xenon	3	1250	750	80	6.4	770	N-3000	NL-C6J
2.5	21	Xenon	3	1250	750	80	6.4	770	N-24-1	NL-C6J/L
2.5	21	Xenon	3	1250	750	80	6.4	770	N-24-1	NL-C6J/P
2.5	21	Xenon	3	1250	1000	80	6.4	770	N-3000	NL-C6J/K
2.5	21	Xenon	3	1250	1000	80	6.4	770	N-24-1	NL-C6J/K-Ne
2.5	21	Xenon	3	1250	1000	80	6.4	770	N-24-1	NL-C6J/KP
2.5	10	Merc.	3	11,000	5500	3	0.75	100	N-1000	NL-KY21A
5.0	10	Merc.	4	10,000	10,000	77	6.4	400	N-12	NL-FG-105
2.5	7	Gas & Merc.	3	1250	1250	6	1.5	120	N-12	NL-323B
2.5	7	Gas & Merc.	3	1250	1250	6	1.5	120	N-12	NL-393A
5.0	4.7	Merc.	4	1500	1500	30	2.5	150	N-12	NL-632B
5.0	7.5	Merc.	3	15,000	15,000	6	1.6	50	N-1000	NL-678
2.5	9	Gas & Merc.	3	1500	1500	30	2.5	250	N-12	NL-710/6011
2.5	9	Gas & Merc.	3	1500	1500	30	2.5	250	N-24	NL-710L
2.5	9	Gas & Merc.	3	3500	3500	30	2.5	250	N-12	NL-710A
2.5	9	Gas & Merc.	3	3500	3500	30	2.5	250	N-12	NL-710AL
2.5	5	Gas & Merc.	3	1250	1250	3	1	50	N-24	NL-714/7021
2.5	6.3	Gas & Merc.	3	1250	1250	8	1	80	N-24	NL-716
2.5	55	Gas & Merc.	3	1500	1500	160	30	2500	N-12	NL-732
2.5	11.5	Xenon	3	1500	1500	40	3.2	560	N-24-1	NL-734/5544
2.5	11.5	Xenon	3	1500	1500	40	3.2	560	N-24-1	NL-734L
2.5	16	Gas & Merc.	3	1500	1500	30	4			NL-740/6856
2.5	16	Gas & Merc.	3	1500	1500	50	2.5	400	N-24	NL-740P/6857
2.5	16	Gas & Merc.	3	1500	1500					NL-740L/7022
2.5	21	Gas & Merc.	3	1500	1500	77	6.4	770	N-12	NL-760
2.5	21	Gas & Merc.	3	1500	1500	77	6.4	770	N-24	NL-760P
2.5	21	Gas & Merc.	3	1500	1500	77	6.4	770	N-24	NL-760L
2.5	25	Gas & Merc.	3	1500	1500	120	10	1000	N-12	NL-770P
2.5	25	Gas & Merc.	3	1500	1500	120	10	1000	N-12	NL-770L
2.5	31	Xenon	3	1700	1700	100 160	18 16	1000	N-24-1	NL-780
2.5	5	Merc.	3	5000	2500	2	.5	50	N-12	NL-5557/FG17/715
5.0	4.5	Merc.	3	1000	1000	15	2.5	200	N-12	NL-5559/FG-57
5.0	4.5	Merc.	4	1000	1000	15	2.5	200	N-12	NL-5560/FG-95
5.0	7.5	Merc.	3	20,000	20,000	11.5	2.5	70	N-1000	NL-5563A
2.5	9	Xenon	3	1250	900	30	2.5	300	N-3000	NL-5632/C3J
2.5	31	Xenon	3	1250	1000	100 160	18 16	1000	N-24-1	NL-5665/C16J
2.5	9	Xenon	3	1250	1000	30	2.5	300	N-3000	NL-5684/C3J/A
2.5	9	Xenon & Neon	3	1250	1000	30	2.5	300	N-24-1	NL-5684-Ne
2.5	9	Xenon & Neon	3	1500	1500	30	2.5	300	N-24-1	NL-5684A-Ne
2.5	6.3	Xenon	3	1250	1000	8	1	77	N-3000	NL-6014/C1K
2.5	21	Xenon	3	1250	1000	80	6.4	770	N-24-1	NL-6989/C6J/KL
2.5	21	Xenon & Neon	3	1250	1000	80	6.4	770	N-24-1	NL-6989-Ne
2.5	9	Xenon & Neon	3	1500	1500	30	2.5	300	N-24-1	NL-7556A-Ne

be replaced with NATIONAL® type except in abnormal applications, especially those involving air temperatures above 140°F, where it is desirable to check ratings.

RECTIFIERS are electronic valves and are the principal means used today for the conversion of alternating current to direct current. Recent refinements and developments have made rectifier tubes available that are especially suited for every need in the rapidly expanding industrial electronic control field.

NATIONAL® Rectifiers are especially designed for industrial applications. They are available in a variety of voltage and current ratings to supply all types of requirements. The sturdy construction, increased efficiency, low maintenance, and reliability of NATIONAL® rectifier tubes have made them one of the leaders in the industrial electronics field. Suffix letters P and L denote panel mounting and lug base types, respectively. All types are 2.5 volts filament unless noted otherwise.

TYPE	REPLACES *	MAX. DIM. INCHES		BASE	CAP	FIL. AMPS	GAS FILLING	MAXIMUM RATINGS			Warranty
		Rigid Lgth.	Bulb Dia.					Peak Inverse Volts	Peak Anode Amps	Average Anode Amps	
NL-RX21A	——	8	2-1/16	A5-11	C1-5	10	Merc.	11,000	3	0.75	N-1000
NL-575A	575A	11-1/8	2-9/16	A4-29	C1-5	10†	Merc.	15,000	10	2.5	N-1000
NL-604 NL-604L	(EL-3C) (EL-3CL)	7-1/2 7-1/2	2-1/16 2-1/16	A4-81 A4-90	——	11.5	Gas & Merc.	900	10	2.5	N-24
NL-606 NL-606L	(EL-6C) (EL-6CL)	8 8-5/8	2-9/16 2-9/16	A4-18 A4-90	——	17	Gas & Merc.	900	25.6	6.4	N-12 N-24
NL-610/7723	——	5-1/2	1-5/8	A4-10	C1-5	9	Xenon	920	30	2.5	N-3000
NL-615	CE-213	6-3/8	2-1/16	A4-10	C1-5	7	Merc.	2000	10	2.5	N-24
NL-616	——	6-1/4	1-5/8	A4-10	C1-5	9	Gas & Merc.	1250	30	2.5	N-12
NL-617	CE-205	8-1/4	2-1/16	Mogul Screw	C1-5	11.5 ♮	Merc.	1000	20	5.0	N-12
NL-619	CE-206	7	2-1/16	G2-3	C1-5	11.5 ♮	Merc.	300	20	6.0	N-12
NL-623	CE-203 CE-215	8-3/4	3-13/16	Mogul Screw	Flex Lead	20	Merc.	500	45	15	N-12
NL-625	CE-202 & B	11-3/4	3-13/16	Mogul Screw	Flex Lead	20	Merc.	900	45	15	N-12
NL-627	CE-207 RX-212	12	3-13/16	Mogul Screw	C1-5	26	Merc.	1000	120	20	N-3000
NL-635/7019 NL-635L/7020 NL-635P/6930	(EL-6B) (EL-6B/L) (EL-6F)	9-1/2 9-1/2 8-5/8	2-1/16 2-1/16 2-1/16	A4-81 A4-90 Panel	C1-5	18	Gas & Merc.	1000	77	6.4	N-12 N-24 N-24
NL-643	——	10	2-9/16	Mogul Screw	Flex Lead	23	Merc.	700	90	15	N-12
NL-649/5834	249R&S, 5834	5-7/16	1-9/16	A4-10	——	7	Merc.	900	10	2.0	N-12
NL-653/5835	BR-3, 5835	5-3/4	2-1/16	A4-10	——	9.5	Merc.	900	12	3.0	N-12
NL-660 NL-660L/7786 NL-660P	EL-6B EL-6B/L EL-6F	8-3/4 9-1/4 8	2-1/16 2-1/16 2-1/16	A4-81 A4-90 Panel	C1-5	21	Xenon	920	80	6.4	N-12
NL-664L NL-664P	—— ——	10-3/4 9-7/8	2-1/16 2-1/16	A4-90 Panel	Flex	25	Gas & Merc.	1000	120	10	N-12
NL-673	673	11-7/16	2-9/16	A4-18	C1-5	10†	Merc.	15,000	10	2.5	N-1000
NL-869B	869B	14-1/4	3	A3-20	C1-9	19†	Merc.	20,000	20	5.0	N-1000
NL-5558/FG32	5558, FG-32	7	1-9/16	A4-10	——	4.5†	Merc.	2000	15	2.5	N-12
NL-6894 NL-6895	6894 6895	10-17/32 10-13/32	2-9/16 2-9/16	A4-29 A4-18	C1-5	10†	Merc.	20,000	11.5	2.5	N-1
NL-7723-Ne	NL-610, 3B	5-1/2	1-5/8	A4-10	C1-5	9	Xenon & Neon	920	30	2.5	N-24-1
NL-7786-Ne	NL-660L	9-1/4	2-1/16	A4-90	C1-5	21	Xenon & Neon	920	80	6.4	N-24-1

*These types, offered by other suppliers, can be directly replaced with the listed NATIONAL® POWER TUBE — complete interchangeability. Tubes listed in parenthesis can be replaced with NATIONAL® type except in abnormal applications, especially those involving air temperatures above 140°F, where it is desirable to check ratings.

♮Filament voltage. is 2.0 volts.

†Filament voltage is 5.0 volts.

THYRISTOR STACKS are heat sink packages with two SCRs mounted in inverse parallel. Their ability to switch high currents at high speeds makes it possible to control both the duration and amplitude of current for constant and accurate welding.

NATIONAL® Thyristor Stacks have compact design for a minimum volume, high transient thermal storage, and double-sided cooling for maximum device utilization. They are factory assembled and full-load tested for ultimate reliability. National's design permits reassembly in the field with original or interchangeable SCRs without rating loss.

Resistance Welder Service

TYPE	REPETITIVE PEAK VOLTAGE VOLTS	TRANSIENT VOLTAGE VOLTS	CHARACTERISTICS COMMON TO ALL TYPES
NL-C501S G7	700	800	Maximum Dimension—Inches:
NL-C501N G7	800	900	Length 9.375, Width 4.250, and
NL-C501T G7	900	1000	Height 3.250.
NL-C501P G7	1000	1100	
NL-C501PA G7	1100	1200	Maximum Continuous Current
NL-C501PB G7	1200	1300	1200 Amperes-RMS.
NL-C501PC G7	1300	1400	
NL-C501PD G7	1400	1500	Maximum Current—@ 1 Hz Conduc-
NL-C501PE G7	1500	1600	tion: 3200 Amperes-RMS.
NL-C501PM G7	1600	1700	
NL-C501PS G7	1700	1800	Type Cooling: Water.
			Mounting Position: Any.

TUBE ACCESSORIES

THERMOSTAT KITS—include thermostat and mounting clamp with spring loaded fasteners. Spencer-Klixon thermostats for both water saving and tube protection — Single pole with one pair of contacts. Contact ratings — 3 amps at 125V, 1.5 amps at 250V, .75 amps at 440V and .50 amps at 600V. Maximum potential — Shell to contacts — 600V dc. Rubber covered flexible leads with spade terminals.

TYPE	USE	CONTACTS	TEMPERATURE OPEN	TEMPERATURE CLOSE	LEAD LENGTH INCHES	TERMINAL BLOCK
C4391N7-51	Water Saver	NO	86° F	96° F	3-1/2	Yes
C4391N7-52	Protection	NC	125	105	3-1/2	Yes
C4391N7-58	Water Saver	NO	86	96	36	No
C4391N7-59	Protection	NC	125	105	36	No
C4391N7-299	Protection	NC	161	141	3-1/2	Yes

WARRANTIES

NATIONAL tubes carry the longest warranties in the industry.

Preferred Thyratrons and Rectifiers are guaranteed for 2 years. These tubes are outstandingly reliable and very conservatively designed. Sockets are available for these types that are highly reliable at the currents involved.

All NATIONAL electronic tubes are designed and built to give the longest life possible under the conditions imposed by the application.

N-24 WARRANTY — 2 YEARS

Preferred NATIONAL Thyratrons and Rectifiers are warranted for 2 YEARS against defects in design, material, and workmanship when used within published ratings. If such defects appear within 2 YEARS after the tube is placed in service, a pro-rata adjustment will be made, based upon the difference between the elapsed life in months at failure and 2 years. A fraction of a month, consisting of sixteen days or more, will be considered a full month of life. A period of fifteen days or less will be deducted from the tube life.

If defects appear within one year after the tube is placed in service, free replacement will be made.

Once a tube has been installed in regular service its life will be considered continuous.

No adjustment will be made if the tube life exceeds 2 years. This warranty expires 2½ years after date of sale to ultimate user and 3 years after date of shipment by manufacturer.

N-24-1 WARRANTY — 2 YEARS

Certain specified NATIONAL tubes are warranted for 2 YEARS against defects in design, material, and workmanship when used within published ratings. If such defects appear within 2 YEARS after the tube is placed in service, a pro-rata adjustment will be made, based upon the difference between the elapsed life in months at failure and 2 years. A fraction of a month, consisting of sixteen days or more, will be considered a full month of life. A period of fifteen days will be deducted from the tube life.

Once a tube has been installed in regular service its life will be considered continuous.

No adjustment will be made if the tube life exceeds 2 years. This warranty expires 2½ years after date of sale to ultimate user and 3 years after date of shipment by manufacturer.

N-12 WARRANTY — 1 YEAR

Certain specified NATIONAL Industrial Tubes are warranted for 1 YEAR against defects in design, material, and workmanship when used within published ratings. If such defects appear within 1 YEAR after the tube is placed in service, a pro-rata adjustment will be made, based upon the difference between the elapsed life in months at failure and one year. A fraction of a month, consisting of sixteen days or more, will be considered a full month of life. A period of fifteen days or less will be deducted from the tube life.

Once a tube has been installed in regular service its life will be considered continuous.

No adjustment will be made if the tube life exceeds 1 year. This warranty expires 1½ years after date of sale to ultimate user and 2 years after date of shipment by manufacturer.

N-1 WARRANTY — 1 MONTH

Certain specified NATIONAL Industrial Tubes are warranted for 1 MONTH against defects in design, material, and workmanship when used within published ratings. If such defects appear within one month after the tube is placed in service, free replacement will be made.

Once a tube has been installed in regular service its life will be considered continuous.

No adjustment will be made if the tube life exceeds 1 month. This warranty expires 1 year after date of shipment by manufacturer.

N-3000 WARRANTY — 3000 HOURS

Certain specified NATIONAL Industrial Tubes are warranted to be free from defects in design, material, and workmanship for a useful life in excess of 3000 HOURS when used within published ratings. If such defects appear before 3000 hours of use, a pro-rata adjustment will be made, based upon the difference between the tube life in hours at failure and 3000 hours.

The tube life in hours is the actual total time the tube has been used.

No adjustment will be made if the tube life exceeds 3000 hours. This warranty expires 1½ years after date of sale to ultimate user and 2 years after date of shipment by manufacturer.

N-1000 WARRANTY — 1000 HOURS

Certain specified NATIONAL tubes are warranted to be free from defects in design, material, and workmanship for a useful life in excess of 1000 HOURS when used within published ratings. If such defects appear before 1000 hours of use, a pro-rata adjustment will be made, based upon the difference between the tube life in hours at failure and 1000 hours.

The tube life in hours is the actual time the tube has been used.

No adjustment will be made if the tube life exceeds 1000 hours. This warranty expires 1 year after sale to the ultimate user and 1½ years after date of shipment by manufacturer.

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