To all whom it may concern:

Be it known, that William D. Coolidge, a citizen of the United States, residing at Schenectady, in the county of Schenectady, State of New York, have invented certain new and useful improvements in Incandescent Cathode Devices, of which the following is a specification.

The present invention relates to thermionic devices, and particularly to X-ray tubes operating by an electron discharge generated substantially independently of gas ionization.

X-ray tubes operating without appreciable positive gas ionization have heretofore been provided with targets, or anodes, of refractory metal, such, for example, as tungsten. An X-ray tube thus provided is capable of operation with a source of alternating current for a short time, or more strictly speaking with an amount of energy input which will not heat the focal spot upon the anode receiving the cathode discharge to a temperature materially in excess of about 750°C, at which temperature the electron emission from heated metals begins to be appreciable. As soon as any part of the anode at the focal spot is heated to a sufficiently high temperature to emit electrons copiously, a so-called inverse electron stream is emitted from the heated part of the anode and strikes the opposite part of the tube, usually the glass wall of the bulb. The result is local heating, cracking of the glass and destruction of the tube.

I have discovered that an anode consisting of a refractory metal, such as tungsten, backed by copper, may be freed sufficiently from gas to be used in a tube operating with a substantially pure electron discharge and that such an anode has a substantially negligible electron emissivity, even when the tungsten at the focal spot is heated to bright incandescence or in fact up to its melting point. My invention includes both a new process of preparing an electron discharge tube and a new tube which will continue to rectify its own current even when the anode becomes in part highly heated.

In the accompanying drawings Figure 1 is a somewhat diagrammatic perspective view of the X-ray tube as a whole; Fig. 2, an enlarged sectional view of the electrodes.

The tube as shown in Fig. 1 comprises a glass bulb 1 having oppositely extending arms 2 and 3 into which the electrodes 4 and 5 are sealed. The cathode as shown more clearly in Fig. 2 comprises a spiral filament 6 of tungsten, or other suitable refractory metal, connected to leading-in wires 7 and 8, which are sealed into glass stem 9 and joined respectively to external contacts 10 and 11. The cathode spiral may be heated by any suitable source of low current, 65 as for example a battery 10, in circuit with a switch 11.

Surrounding the cathode 4 is a focusing device 22 comprising a cylindrical portion and a hemispherical portion. The object 70 of this device is to cause the cathode rays to converge, the focus of the pencil of rays being directed upon a target or anode 12 located opposite the cathode. The focusing device 22 is supported upon the wires 13 and 14 carried by the stem 7. The conductor 6 passes through a hole in the end of the tube 14. The three wires, 5, 6 and 13 are held in place by a bridge 15 suitably insulated with mica, or like material.

The anode comprises a tungsten button 15 and a mass of copper 17 electrically joined to the tungsten. This copper mass is treated to remove dissolved gases, preferably by adding to the copper while molten a small quantity of oxidizable boron material, as for example, boron sub-oxide or boron carbide. The degased copper is then melted 90 in a vacuum in contact with the tungsten and under these conditions thoroughly wets the surface of the tungsten and forms a perfect molecular union therewith. This form of anode is described in my prior Patent No. 1,162,339.

The anode stem may be mounted upon a split iron tube 18 by iron wire 19. This tube 18 is in turn inserted into a glass tube 20. The anode stem 17, is joined to a short platinum ring 21 which is sealed into the glass wall of the arm 3 of the tube. The body of copper carrying the button of tungsten projects outside of the tube. External to the X-ray tube the anode stem is in effective thermal relation with a radiator 22, consisting of a series of plates spaced apart, consisting of copper, or other good heat conducting metal.

The object in making of considerable length the anode stem 17, which is continu-
ons with the copper backing member 17, is to provide without appreciable oxida
5 tion of heat conductivity an extended narrow space within the evacuated bulb between the stem
17, and the wall of the anode arm 3 to sup
press the passage of electrons to the glass
wall adjacent the anode seal. The narrow-
ess of this space insures a high space charge
for stray secondary cathode rays, that is,
the impeding effect of the electrical charge
of the electrons upon each other is relative
high, thereby preventing the accumulation of
high negative charges upon the glass wall
adjacent the anode seal which would re
5 suit in rupture of the glass at high impressed
voltages.

The tube thus assembled is exhausted to
a good vacuum and then dry hydrogen gas
with a pressure of about an atmosphere is intro
duced, and is again exhausted. The tube is
then again filled with hydrogen at about at
mospheric pressure and heated to about 550º
C. for about fifteen minutes. The tube there
upon is exhausted to the lowest pressure ob
tainable with a molecular pump, or con
densation mercury vacuum pump, the con
duct of connecting the bulb to the pump hav
ing a liquid air trap. In my opinion the
beneficial effect of this hydrogen treatment
is due to the removal of oxygen from the
target.

When the exhaust has been made as com
plete as possible and the tube has cooled,
a discharge is cautiously started, while the
cathode is heated to incandescence, thereby
disengaging further amounts of gas from the
anode, as well as incidentally from the cathode. This treatment is continued, the
gas evolved being continuously removed, as
described in my prior Patent 1,293,495 of
October 31, 1916. When finally a discharge
may be obtained between cathode and anode,
substantially free from accompanying evid
ences of gas ionization, the tube is scaled
off from the pump.

I have found that a tube thus prepared may be connected to an alternating source of
current, such as the secondary of a trans
former 22 and that the tube with the cathode
heated to incandescence will conduct but
such half waves of current as are negative
with respect to the cathode and will not
conduct waves of opposite polarity although
the tungsten button upon which the cathode
rays are focused is heated to bright incan
descence. In fact, in some cases I have actu
ally melted tungsten at the focal spot dur
ing the operation of the tube without ob
taining an inverse discharge at the anode
with its accompanying manifestation of bom
bardment of the wall near the cathode
end of the tube by cathode rays.

In my opinion this surprising phenomenon can be explained by the fact that in
spite of the great care exercised to remove
dissolved gases from the copper, some gas,
particularly a trace of oxygen, remains dis
solved in the copper, or combined there
with, and that some of this oxygen acts upon
the heated tungsten and produces some
changes, chemical or physical, at the incan
descent tungsten surface, suppressing or
greatly inhibiting electron emission. Some
of this oxygen may be evolved in the gase
ous state from the incandescent tungsten,
but is immediately absorbed again by the
cooler copper in the vicinity and may then
again diffuse through the copper to the
tungsten button.

I have found that the bulb of a tube em
bodying my invention may be made very
much smaller than for the former types of
X-ray tubes. Because of its simplicity and
ease of operation, an X-ray tube embodying
my present invention is well adapted for
portable X-ray outfits, particularly for field
work in military operations. It is also well
suited for bedside work in hospitals.

What I claim as new and desire to secure
by Letters Patent of the United States, is:

1. An electron discharge device compris
ing an envelope, a cathode, means for in
dependently heating said cathode to incandes
cence, and an anode, the electron emissivity
of which is negligible even when heated in
part to incandescence.

2. An electron discharge device compris
ing an envelope, a cathode, means for in
dependently heating said cathode to incandes
cence, and an anode, the electron emissivity
of which is negligible even when said anode
is heated to incandescence.

3. An X-ray tube comprising an envelope,
a cathode, of refractory material, means for
heating said cathode by passage of current,
means for focusing an electron discharge
from said cathode, an anode or target for re
ceiving said discharge, the electron emissiv
ity of the focal area of said target being negli
gible even when heated to incandescence.

4. The combination of a source of alter
nating current and an electron discharge
device connected thereto, said device com
prising an envelope, a cathode, means for in
dependently heating said cathode to incandes
cence, and an anode the electron emissiv
ity of which is negligible even when heated
in part to incandescence.

5. The method of treating an anode of
an X-ray tube to be operated with a substan
tially pure electron discharge of an X
-ray tube which consists in filling said tube
with hydrogen gas, heating the bulb to a
temperature of several hundred degrees cen
tigrade, evacuating said hydrogen filling to
a pressure so low that the effects of gas ion
ization will be inappreciable when a dis
7. An X-ray device comprising a cathode operable at incandescence, an anode comprising a button of tungsten and a backing of copper molecularly joined to said tungsten, means for directing an electron discharge from said cathode upon said tungsten target, an anode stem adapted to effectively conduct heat away from said copper backing and an inclosing sealed envelop having an arm shaped to provide an extended narrow space about said anode stem, said device being freed from gas sufficiently to enable an electron discharge to occur therein without appreciable gas ionization.

In witness whereof I have hereunto set my hand this 3rd day of December 1917.

WILLIAM D. COOLIDGE.