CLIPPER THYRATRON

DESCRIPTION — The 7455 is a zero bias, short ionization time hydrogen thyratron specially designed to pass high fault currents as an inverse clipper in line-type radar modulators. The tube, when triggered, terminates the pulse-forming network in its characteristic impedance thereby reducing the inverse voltage to zero during both normal and load fault conditions. It also reduces to a minimum the inverse spike energy that otherwise would have to be dissipated by the switch tube anode.

The low anode 'firing' voltage and ability to carry very large peak (fault) currents make a hydrogen clipper thyratron ideal for this application. The 7455 is capable of clipping at a switch-tube power level of 33 megawatts in a line-type modulator. A hydrogen reservoir is included to promote long life by providing a method of automatically replenishing hydrogen lost by 'cleanup'.

ELECTRICAL DATA

	Minimum	Bogey	Maximum	
Heater Voltage	4.75	5.00	5.25	Volts
Heater Current—Ef = 5.0 volts	15	20	25	Amperes
Cathode Heating Time	3	—	—	Minutes
Anode Voltage Drop	—	—	300	Volts
Altitude	—	—	10,000	Feet
Ambient Temperature	—55	—	+75	Degrees Centigrade

MECHANICAL DATA
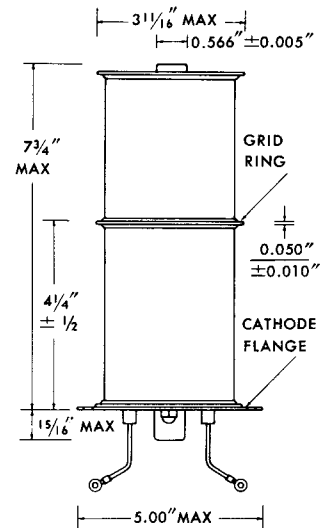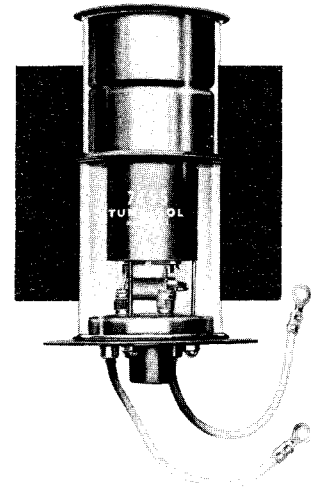
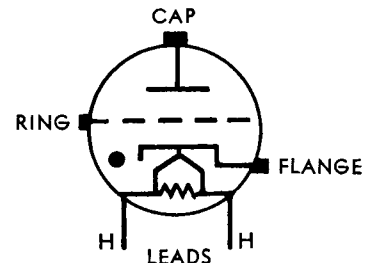|	
Type of Cooling	Convection
Mounting Position	Base down or horizontal
Maximum Net Weight	2¼ pounds
Mounting Data	Three ⁵⁄₁₆ in. diameter holes spaced 120° on 4⅜ in. diameter
Chassis Hole	3 inches
Grid Connector	Tung-Sol/Chatham Part No. 2556-A
Shock—Maximum	500G acceleration with 1 millisecond duration

MAXIMUM RATINGS — ABSOLUTE VALUES

	Min.	Max.	
D C Anode Voltage, Inverse (Note 1)	—	33	Kilovolts
D C Anode Voltage, Critical (Note 2)	1,000	—	Volts
Cathode Current (Note 3)			
RMS—Continuous	—	8.5	Amperes
RMS—Fault—Averaging Time 3 seconds	—	16	Amperes
Peak—Continuous	—	800	Amperes
Peak—Fault	—	2,900	Amperes
Operating Frequency (Note 4)	—	2,500	Cycles-per-second
Grid Voltage—Peak Forward	600	—	Volts
Grid Voltage—Peak Inverse	—	3,000	Volts
Grid Trigger Current—Peak	6	15	Amperes
Trigger Pulse Width (Note 5)	0.5	—	Microsecond
Trigger Lead Time (Notes 6 & 7)	0.2	—	Microsecond

Notes:
1. Inverse anode voltage in a clipper tube is defined as the peak voltage that can be impressed between anode and cathode with a polarity opposite to that producing current flow in the tube. Generally, it has the same magnitude as the maximum network voltage.
2. Critical anode voltage in the clipper tube is defined as the minimum anode voltage at which anode conduction occurs. The actual rating allows sufficient safety factor to enable minimum delay of anode conduction.
3. Cathode Current
   a. RMS cathode current is defined as the maximum effective current flowing through the clipper tube under any condition of operation for a period not exceeding the average time. The interval over which the averaging time is applied must include the period in which the maximum rms fault current is encountered.
   b. Peak fault current is defined as the maximum value of instantaneous current flowing in a clipper tube when a fault occurs in the load circuit.
   c. In determining circuit parameters, care must be observed to insure that the nominal rms current (without load faulting) is of such a value as to prevent the rms current (with load faulting) from exceeding the rating during the specified average time.
4. The maximum operating frequency does not necessarily represent the upper limit, but is the highest frequency at which tests have been conducted.
5. The trigger pulse width should not exceed the load pulse width plus the trigger pulse lead time.
6. The minimum trigger lead time is defined as the period between the time at which the leading edge of the unloaded grid pulse reaches 50 percent of its maximum value and the time at which the clipper tube anode becomes positive.
7. The maximum trigger pulse lead time should not exceed 80 percent of the trigger pulse width.

OUTLINE DRAWING

3¹¹⁄₁₆″ MAX
0.566″ ±0.005″
7¾″ MAX
GRID RING
0.050″ ±0.010″
4¼″ ± ½
CATHODE FLANGE
¹⁵⁄₁₆″ MAX
5.00″ MAX

CAP

RING

FLANGE

H LEADS H

BOTTOM VIEW

APPLICATION NOTES

The typical line-type radar modulator comprises a switch tube, a load, a pulse-forming network, and usually a clipping device. The load is normally a magnetron, or klystron coupled to the modulator by a pulse transformer. Most often, the network is negatively matched, that is, the impedance of the load is smaller than the characteristic impedance of the network. The result of this mismatch is that a negative voltage remains on the network after the main discharge pulse, and the voltage is added to the supply voltage on the next charging cycle. When a load fault occurs, the mismatch is increased and the negative voltage rises placing a higher positive voltage on the pulse-forming network. Prolonged faults produce successively higher network voltages resulting in dangerously high voltages on the circuit components. The negative mismatch voltage also produces an inverse current pulse in the switch tube immediately after the main discharge pulse. As this current decays very rapidly, an inverse spike voltage appears across the tube. The resulting energy must be dissipated by the switch tube anode.

The main advantages gained by employing a clipper device in a modulator circuit include:

    a. protection of components from excess voltage produced during load faults,

    b. regulation of output pulse amplitude, and

    c. reduction of inverse spike energy that has to be dissipated by the switch tube.

FIGURE 1. END OF LINE CLIPPER

FIGURE 2. FRONT OF LINE CLIPPER
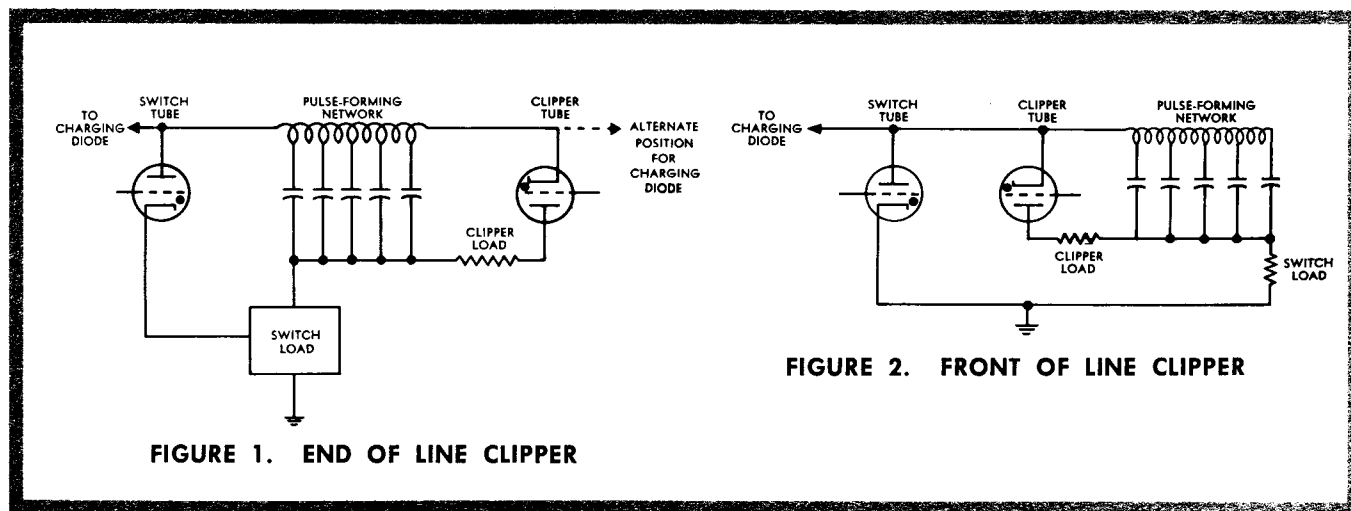
A gas tube with its inherent low internal impedance and high peak and average current handling capacity is ideally suited for clipper applications as it is not practical to obtain optimum clipping with a vacuum device.

Two of the most popular clipping methods are illustrated in figures 1 and 2. The configuration of figure 1 is preferred. In it the clipper tube is connected across the far end of the pulse-forming network in series with a resistive load the value of which approximates the network impedance. With the clipper in this location, the inverse spike can be almost completely eliminated and simple triggering means can be employed. In the front-of-line clipper, illustrated in figure 2, if the load impedance is less than the network impedance, as is usually the case, a resistor must be inserted in series with the clipper tube. The value of this resistance should be chosen to approximate the network impedance.

The relation between switch-tube currents and clipper-tube currents in a line modulator are shown in graphic form in figures 3, 4 and 5. The ratio of switch tube to clipper tube peak current as a function of R_L/Z_O is shown in figure 3. During normal operation, the clipper tube peak current is usually no greater than one-half the switch tube peak current. However, under a fault condition, the clipper tube peak current is 0.7 times the switch tube fault current, and may be four times the normal clipper tube peak current depending on the ratio R_L/Z_O. The ratio of the rms clipper tube to switch tube currents as a function of R_L/Z_O with the ratio of rise time to pulse width (f) as a parammeter, is shown in figure 4. During a load fault, R_L becomes zero and the rms clipper current is just one-half the rms switch tube fault current. However, under certain conditions the rms clipper current may be as much as four times the steady-state value. A similar graph, figure 5, presents the relationship between the average currents in the switch tube and the clipper tube.
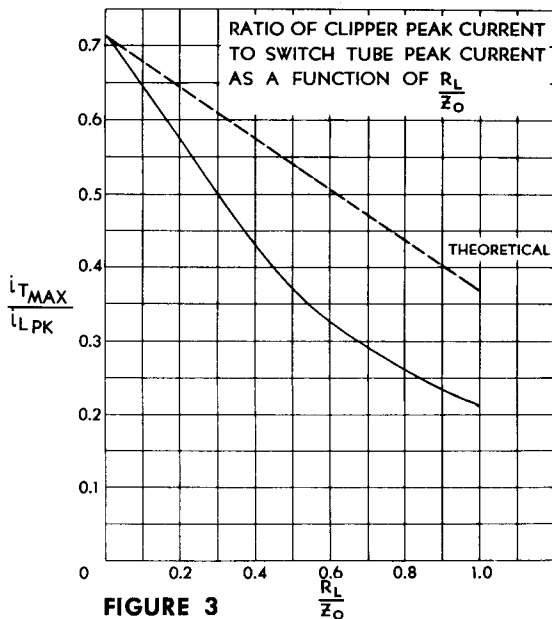

FIGURE 3 — RATIO OF CLIPPER PEAK CURRENT TO SWITCH TUBE PEAK CURRENT AS A FUNCTION OF $\frac{R_L}{Z_O}$

$\frac{i_{T_{MAX}}}{i_{L_{PK}}}$

THEORETICAL

FIGURE 4 — RATIO OF CLIPPER r.m.s. CURRENT TO NOMINAL LOAD r.m.s. CURRENT AS A FUNCTION OF $\frac{R_L}{Z_O}$ AND f

$\frac{i_{r.m.s.}}{i_{L r.m.s.}}$

f=0.5, f=0.4, f=0.3, f=0.2, f=0.1, f=0.05, f=0

FIGURE 5 — RATIO OF CLIPPER AVERAGE CURRENT TO SWITCH TUBE AVERAGE CURRENT AS A FUNCTION OF R_L AND f $\frac{}{Z_O}$

$M = \frac{i_{AV}}{i_{L_{AV}}}$

f=0.5, f=0.4, f=0.3, f=0.2, f=0.1, f=0

$i_{T\,max}$ = peak clipper tube current

$i_{L\,peak}$ = peak load current

R_L = load resistance

Z_O = characteristic network impedance

f = ratio of load current rise time to pulse width

i_{rms} = rms clipper tube current

i_{Lrms} = rms load current

i_{av} = average clipper tube current

i_{Lav} = average load current

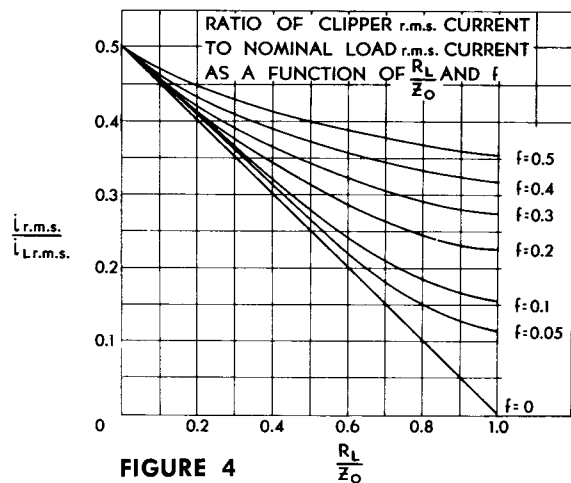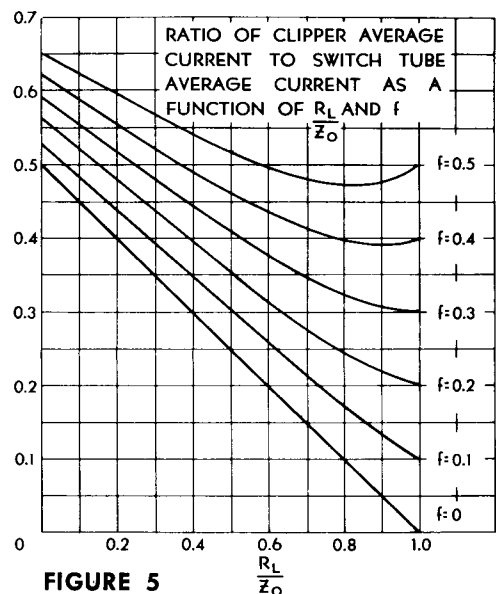While a thyratron clipper requires an additional grid connection not needed for a diode clipper, the thyratron can be triggered at the optimum time demanded by the circuit. This fact, plus the inherent ability of a grided tube to hold off high inverse voltage, makes the thyratron a trouble-free clipping device.

The clipper tube may be triggered in a number of ways. It has been determined that the most effective clipping occurs when the clipper tube grid is triggered at least several hundred millimicroseconds before the initial voltage wave reaches the far end of the line. The simplest triggering method consists of a one-turn primary pulse transformer and is illustrated in figure 6. In this circuit, a trigger pulse of the proper lead time, polarity and amplitude is obtained directly from the pulse-forming network. Thus triggering is accomplished in a simple manner without loading the pulse-forming line. The methods shown in figures 7 and 8 will also fill the triggering time requirement. However, if the divider impedances are too low, the output pulse shape will be affected. The trigger circuit of figure 8 can also be employed in "tailbiting" and voltage clamping service.
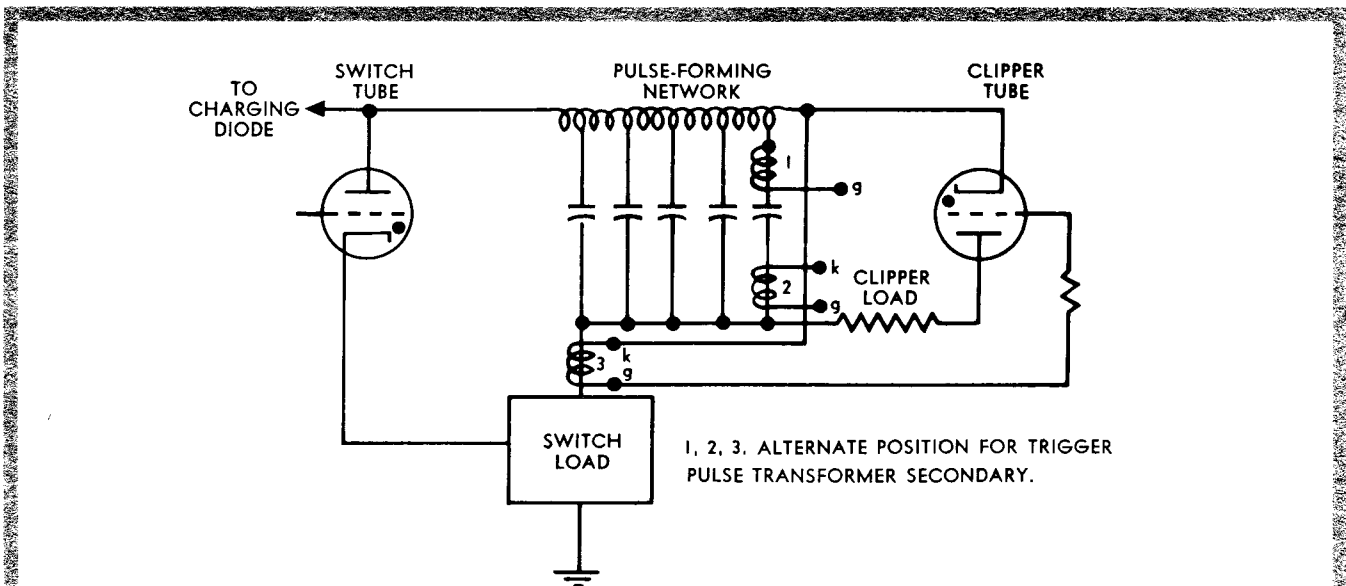
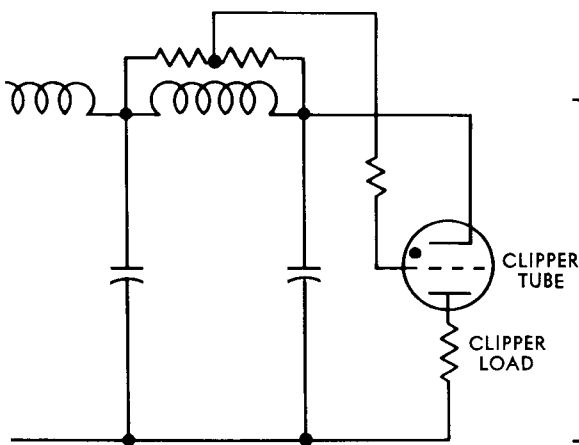

FIGURE 6. TRANSFORMER-COUPLED TRIGGERING CIRCUIT

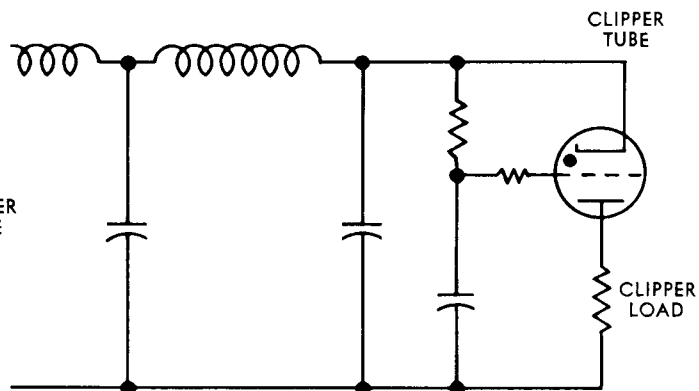**FIGURE 7.**
RESISTOR-COUPLED TRIGGERING CIRCUIT

FIGURE 8.
R-C TRIGGERING CIRCUIT