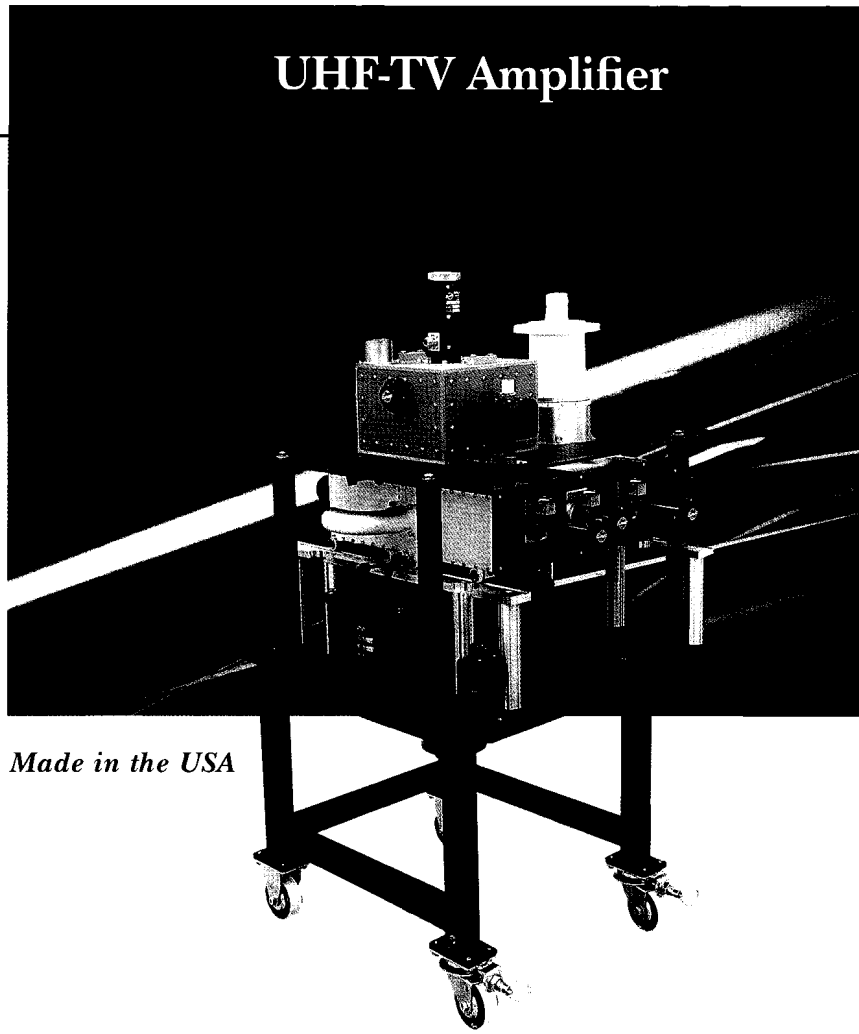
2KDW60LC Klystrode® IOT

UHF-TV Amplifier

- 64 kW Peak-of-Sync in Vision-only Service
- 42 kW Peak-of-Sync, 4.2 kW single carrier sound in Common Amplification Service
- Figure-of-Merit of 120% in Vision-only; 100% in Common Amplification
- High gain amplifier - 22 dB minimum
- Long life, high reliability with dispenser type cathode and pyrolytic grid
- Single tube and circuit - 470 to 810 MHz
- User-friendly tuning and tube replacement
- Compact size with "collector (water) down"
- Water cooled collector and body - air cooled circuits and electron gun
- Worldwide Product and Applications Support



Made in the USA

The EIMAC 2KDW60LC Klystrode® Inductive Output Tube (IOT) is a high efficiency amplifier tube for use in UHF television service in the output stages of vision, sound, combined vision and sound and ATV transmitters. The IOT has a magnetically focused electron beam which is density bunched by an RF cavity-driven grid. With moderate amplitude and phase precorrection the tube can be operated in class AB mode with very low average beam current thus saving beam power which would otherwise be wasted as heat in the collector.

A single tube, 2KDW60LC, and associated circuit assembly, CV-5000C, cover the UHF-TV band, 470 to 810 MHz (bands IV and V).

The circuit assembly, CV-5000C, is designed with a number of features to enhance performance of the IOT as well as provide for ease of amplifier tuning and maintenance. The assembly consists of the input cavity, IC-550, the output cavity, OC-550, magnet assembly, arc detector, and a rugged wheeled support stand. Tube installation and replacement is user-friendly and simple to accomplish. Tuning of a replacement IOT requires only a brief touch up or fine tuning prior to use. Simple controls are provided for tuning and procedures have been incorporated that require a minimal amount of test equipment to optimize tuning.

The electron gun and cavities are forced air cooled with user supplied filtered air. The IOT body and collector are water cooled.

The Klystrode IOT may be operated in combined sound and vision mode service at 42 kW peak-of-sync with suitable precorrection. This mode of operation results in extremely simple, compact, and economical transmitter design.

The Klystrode IOT is also suitable for operation as an FM aural power amplifier. It may be operated in the FM mode at 10% to 20% of the peak-of-sync power of a companion visual mode IOT with a common beam supply.

In HDTV digital transmission the Klystrode IOT can be used at up to 60 kW peak power or greater, depending on the peak-to-average level (for details please contact Varian Power Grid Tube Products (PGTP), Klystrode IOT Applications Engineering).

varian®
power grid tube products

General Characteristics[1]

SUMMARY DATA

Frequency Range .....470 to 810 MHz
Sync output power (at IOT flange) .....64 kW
Power Gain .....22 dB
Beam Voltage .....30 to 32 kV

ELECTRICAL

Cathode: .....Dispenser type
DC Heater Voltage .....9 to 12 V
DC Heater Current .....9.5 A (nominal)
Ion pump reference potential .....GROUND
Ion pump operating voltage .....+3.5±0.5 kV
Internal ion pump supply impedance ..500K ohms, approx.
Maximum cold start DC Heater Current 15A
Heater warm-up time (minimum) .....5 minutes
Magnet - Part of CV-5000C Circuit Assembly:
DC Voltage (maximum) .....11 V (6 V nominal)
DC Current (maximum) .....28 A (20 A nominal)

MECHANICAL

Klystrode IOT

Length .....(overall) 25.9 in (65.8 cm) nominal
Diameter .....(overall) 14.7 in (37.3 cm) nominal
Mounting position .....vertical, collector end down
Net weight .....45 lbs (20 kg) approx.

CV-5000C Circuit Assembly

Input .....RF connector type N
Output RF connector 3 1/8 inch 50 ohm coaxial line
or 4 1/16 inch 50 ohm coaxial line (user specified)
Net weight of RF Circuits .....110 lbs [50 kg]
Net weight of magnet assembly .....265 lbs [220 kg]
Net weight of circuit assembly .....375 lbs [170 kg]

Cooling

Airflow to cavities and cathode
terminal .....90 cfm (2.6 m^3/min) (see note 3)
Static pressure
head .....5.0 inches water (1.30 kPa) (see note 4)
Inlet air temperature .....50°C max
Minimum water flow rate for body
2.0 U.S. gal/min (7.6 l/min)
Body pressure drop at 2 U.S. gal/min
(7.6 l/min) 15 psi (103 kPa)
Minimum water flow required for collector
15 U.S. gal/min (57 l/min)
Collector pressure drop at 15 U.S. gal/min 15 psi (104 kPa)
Maximum Inlet pressure .....60 psi (414 kPa)
Water Outlet temperature .....65°C max
Water Inlet temperature .....50°C max

Tube Protection

Arc detector (part of OC-550 output cavity
assembly) (See note 5):
Photo resistor .....cadmium sulphide
Minimum dark resistance .....750K ohms
Resistance at 1 foot-candle .....18K ohms
Resistance at 2 foot-candle .....8K ohms
Resistance at 100 foot-candles .....550 ohms
Maximum voltage (peak) .....100 V
Maximum temperature .....75°C
Test lamp .....28 V at 1.5 mA
Connections/cable .....(see figure 5)
Crowbar:
[Required for proper operation and protection of the
IOT. Energy input must be limited to less than 4
joules maximum. See note 6.]
Must remove high voltage from the tube within 20 µsec if
any of the following occurs:
- excessive rise in beam current (di/dt)
- an arc in the output cavity
- an excessive power reflection

Maximum Ratings (Absolute Values)

[If maximum rating for any parameter listed below is exceeded, the beam voltage must be removed within 100 msec from the instant at which the rating is exceeded. Beam voltage must not be applied for at least 5 seconds after the event.]

Heater starting current (peak) .....15 A
Heater supply ripple .....±5%
Beam voltage .....35 kV (See note 7)
Average beam current .....4.0 A
Body current .....120 mA
Collector dissipation .....55 kW
Load VSWR (see note 8) 1.5:1
Temperature of any part of tube envelope .....200° C
Peak drive power .....430 W
Grid to Cathode Bias Voltage .....-100 VDC (See note 9)
Grid dissipation .....20 W
Ion pump current (beam on) 20 µA
Output Power Ratings:
- Vision only service:
  - 66 kW peak-of-sync at 32 kV
- Common Amplification:
  - 75 kW peak at 32 kV
  - 62 kW peak at 30 kV

Visual Service:
- RF output power (peak-of-sync NTSC) .....64 kW
- RF output power (black level NTSC) .....35 kW
- RF output power
(average picture level NTSC) .....12.9 kW

1 Characteristics and typical operating conditions are tentative. These figures may change without notice as a result of additional information. Varian should be consulted before using this information for final equipment design. Klystrode®, Eimac®, and Vacion® are registered trademarks of Varian Associates, Inc.

- Heater requirements .....9 - 10.5 A
- Beam voltage .....32 kV
- Beam current (peak-of-sync) .....3.6 A
- Beam current (black level) .....2.2 A
- Beam current (gray level) .....1.4 A
- Beam current (average picture level NTSC) 1.6A
- Grid bias voltage with respect to cathode voltage: 10 to 100 V, negative with respect to cathode (regulated power supply). Supply to be swamped with 100 ohm bleeder resistor.
- Drive power (peak-of-sync) .....400 W
- Conversion efficiency (peak-of-sync) .....55.0 %
- Figure of Merit .....120 %
- Linearity .....15 % (typical)
- Differential gain (f-sc=3.58 MHz) .....15 % (typical)
- Differential phase (f-sc=3.58 MHz) .....8 deg (typical)
- Incidental phase .....6 deg (typical)

Aural Service

• *RF output power*	*13 kW*	*6.4 kW*	*6.4 kW*
Heater requirements	9.5 A	9.5 A	9.5 A
Beam voltage	32 kV	32 kV	16 kV
Beam current (see note 3. "Additional Considerations")	1.2 A	0.67 A	1.1 A
Drive power	82 W	40 W	40 W
Power Gain	22 dB	22 dB	22 dB

Common Amplifier Service (Mono Sound) (See note 10)

- Visual output power (peak-of-sync) .....42 kW
- Aural output power .....4.2 kW
- Instantaneous peak-of-sync output power .....73 kW
- Heater requirements .....9 - 10.5 A
- Beam voltage .....32 kV
- Quiescent beam current .....0.35 A
- Grid bias voltage with respect to cathode voltage 10 to 100 V, negative with respect to cathode (regulated power supply). Supply to be swamped with 100 ohm bleeder resistor.
- Beam current (peak-of-sync) (vision content only) ....2.6 A
- Drive power (visual peak-of-sync) .....300 W
- Drive power (aural) .....40 W
- Figure of merit .....100 %

NOTES

1. **Heater Current**
   IOT transmitter designs incorporating the 2KDW60LC must make provision in design for heater currents of up to 15 Amps peak (9 to 10.5 Amps typical) measured at the connection terminals on the IC-550 input circuit.

2. **Passive Standby and Quick-Start Modes**
   The Klystrode IOT offers the designer several options when operated in a transmitter in passive standby operational mode:

Background Heat Passive Standby Mode

The Klystrode IOT must be operated with a background heater current of 8.0 Amps during periods of passive standby.

Passive standby is defined as any time period exceeding 30 minutes when the IOT is operated without application of beam voltage yet maintains the heater voltage on. In this mode of operation, the ion pump as well as all air cooling must remain on in full operating condition.

In the event the passive standby transmitter is needed for full operational service, the heater current should be raised to 9.5 Amps and other auxiliary supplies activated. The high voltage and RF drive should be applied at least two minutes later.

Background heat must have been applied for a minimum of five (5) minutes from the cold start or transmitter turn-on prior to full operational service. Alternatively, both "active" and "standby" transmitters may be started from a cold start using the normal, 5 minute minimum starting procedure. The "standby" transmitter is then switched to background heat and thus readied for full operation if required.

Where background heat passive standby is the normal mode of operation with a pair of transmitters, the transmitter designated as the "standby" must be switched to "active" status after a period not exceeding 14 days and must remain designated "active" for a period of not less than 7 days.

The crowbar circuit should be fully operational while the transmitter is in the "standby" mode.

Filament hours under the conditions of background heat are not included in warranty hour calculations or considerations, provided that all above conditions are met and that there are proper means incorporated in the design to distinguish background heat from normal filament hours.

NOTE: It is not necessary to operate the Klystrode IOT under standby conditions. Quiescent current stability is the same whether the device is brought up from a cold condition or from passive standby.

Soft Start

It is recommended that a soft start procedure be utilized in the application of RF drive when the IOT is brought up to full operational status from either cold or background heat.

The RF drive must be applied only after application of the beam voltage and with a typical rise time of 4 seconds.

Quick Start Procedure

To start the IOT from background heat in a time shorter than two minutes, a Quick Start Procedure is available from Varian. Users considering this procedure should contact Varian PGTP, Klystrode IOT Applications Engineering.

Near-Instantaneous Start - Quiescent Passive Standby
A nearly instantaneous start to full operational status is achievable by operating the "standby" transmitter in a quiescent passive standby mode where only the RF drive is removed from the IOT and the tube is operated with normal beam on conditions. In this mode, overall system efficiency will be slightly less than normal. However, this mode ensures that the standby tube is maintained in as near an optimum condition (as near to operational parameters) as possible and that it is available for immediate use or near-instantantaneous start, subject to the normal soft start conditions. Under this condition, standby filament hours are counted against warranty. Users considering this mode of operation are encouraged to contact Varian PGTP, Klystrode IOT Applications Engineering for details.

3. This value applies to transmitters at sea level where air density is 0.076 lb/ft^3 (1.22 kg/m^3). At higher altitudes where air density is consequently reduced, the volume of cooling air flow must be increased in the ratio of air density at sea level to air density at altitude in order to maintain the required mass flow.

4. Measured by a manometer at the input pipe to the circuit assembly.

5. A single detector of type EG&G VT20A432 is installed on the output cavity assembly.

6. **Fault Protection**
A crowbar system capable of limiting energy dissipation in the tube in the event of an internal arc must be provided. This is in addition to any normal overcurrent, over-voltage, or cooling interlock means of circuit and component protection. No more than four (4) joules of energy may be dissipated in the tube structure.

A protective resistance of approximately 15 ohms should be connected in series with the tube anode (in the HV beam supply lines) to absorb power supply stored energy in the event of an internal arc occurrence. With the generally high stored energy in an IOT transmitter an electronic crowbar circuit is required to discharge power supply capacitors in a few microseconds after the start of an arc.

To conduct a protection circuit test which will verify adequate tube protection, short the HV power supply to ground through a fast acting vacuum switch or other suitable high speed, high voltage switch and a 6-inch (15.24 cm) length of #40 AWG (0.079 mm diameter) soft copper wire. If the total energy delivered is less than four (4) joules, the wire will remain in tact. This test will verify if the tube is properly protected.

For more detailed information an application bulletin and assistance is available. For this or other information or details concerning tube protection contact Varian PGTP, Klystrode IOT Application Engineering.

7. The high voltage power supply must be designed and connected to the IOT such that high voltage overshoots are minimized at turn-on and that they do not exceed the stated maximums.

8. Typical operating performance will be obtained for a load VSWR of less than 1.1:1. The tube will not sustain damage for a load VSWR of less than 1.5:1.

9. Grid bias should be provided by a regulated power supply adjustable over the range of 10 to 100 volts negative with respect to the cathode voltage. The regulated supply should be swamped with an approximately 100 ohm bleeder resistor. Adjust the supply to provide the required quiescent current as specified with each tube.

10. Common amplifier service employs a single IOT to transmit both visual and aural services. The data herein assumes that common amplification includes the transmission of a single sound carrier. The peak instantaneous RF output for monaural (mono) sound is calculated by the formula:

$$P = V(1+\sqrt{A})^2$$

where P is the peak RF output power, V is the peak-of-sync visual output power, and A is the ratio of aural power to peak-of-sync visual power.

If stereophonic (stereo) sound is to be transmitted, the peak instantaneous RF output power is calculated by the formula:

$$P = V(1+\sqrt{A}+\sqrt{S})^2$$

where S is the ratio of stereo carrier power to peak-of-sync visual power.

11. The figure of merit **(FOM)** is calculated as the total peak-of-sync **output power** (visual and aural) divided by an **Average Input Picture** Power, consisting of sync and **blanking pulses** and a mid-gray level picture as follows:

$$FOM = \frac{P_V + P_A}{P_{IN(avg)}} * 100\%$$

where P_V is the peak-of-sync vision power, P_A is the aural power, and $P_{IN(avg)}$ is the beam power utilized when transmitting a visual signal consisting of mid-gray picture and sync and blanking pulses.

The figure of merit is a function of the bandwidth of the transmitted signal from the IOT output circuit. The following data is typical FOMs obtained for different TV standards as well as vision-only and common amplifier mode:

Vision-only Mode

TV Standard	*Bandwidth (MHz)*	*FOM (%)*
M	6	135
B	7	128
I	8	120

Common Amplifier Mode

TV Standard	*Bandwidth (MHz)*	*FOM (%)*
M	6	100
B	7	85
I	8	75

12. APL (Average Picture Level) is considered to consist of normal NTSC signals including vertical blanking. Average Picture Content is approximated with a ramp signal.

13. **Additional Considerations:**

MECHANICAL

Circuit Assemblies
Included are a magnetic frame, magnet coil, input cavity, double-tuned output cavity, and input and output couplers. Circuit assembly type number:
CV-5000C (470 - 810 MHz)

Vacion® Pump
The tube is provided with a two-liter ion pump and its associated permanent magnet. The primary function of this device is to monitor the condition of tube vacuum by a current meter. A power supply and a cable assembly are required for operation. Typical voltage is 3.3 kV with a maximum current of 5 mA. An overload circuit should be arranged to cut off the beam voltage and RF drive at 20 µA and to cut off the heater voltage above 200 µA. The Vacion pump power supply can be any of a variety of types. A satisfactory recommended unit is Varian type number 921-2001. The corresponding cable assembly is Varian type number 924-0741.

Cooling
The tube and circuit assembly are water and forced-air cooled. Air is required for cooling the input circuit of the tube. For output power greater than 6 kW air is blown through the output cavity and load coupler. Approximately 60 cfm (1.7 m^3/min) at 1/4 inch of water (65 Pa) pressure is required.

Body Water Cooling
There are two body water cooling circuits; one for the anode and another for the IOT tailpipe. Each requires a minimum flow of 1.5 gpm (5.7 l/min)at a pressure drop of approximately 25 psi (170 kPa).

Collector Water Cooling
Typical minimum flow rate is 25 gpm (95 l/min). Pressure drop at this flow rate is approximately 25 psi (170 kPa). Maximum inlet water temperature is 50° C.

Input Cavity Cooling
Forced air-cooling is required with a minimum flow of 7 cfm (0.2 m^3/min) at sea level, at an inlet temperature of 35° C maximum, and a pressure drop of approximately 1.5 inches (390 Pa) of water.

ELECTRICAL

High Voltage
Normal operating voltages used with this tube are deadly. Equipment must be properly designed and operating precautions must be followed. Design equipment so that no one can come in contact with high voltages. Interlock switches must not be bypassed to allow operation with access doors or panels open or removed. Remember, ***high voltage can kill!***

Radio-Frequency Radiation
Exposure to strong RF fields should be avoided, especially at frequencies above 300 MHz, where energy absorption by the human body is significant. The human eye is particularly sensitive. Prolonged exposure to RF radiation should be limited to 10 mW per square centimeter (U.S.A. Occupational Safety & Health Administration standard). ***Cardiac pacemakers may be effected.***

X-Radiation Hazard
High-vacuum tubes operating at voltages higher than 15 kV produce progressively more dangerous X-ray radiation as the voltage is increased. This tube, operating at its rated voltages and currents, is a potential X-ray source. Shielding may be required on all sides of tubes operating at these voltages to provide adequate protection throughout the life of the tube. If there is any question as to the need or adequacy of shielding, an expert in the field of X-ray radiation should be consulted.

Heater Voltage
Voltage should be adjustable over the range from 9 to 12 volts and measured with an accurate voltmeter. Ripple should not exceed ±5%. During turn-on, current should be limited to 15 Amps. Alternatively, a step-start system may be used. The heater connection must be negative, with the cathode positive.

Cathode/Grid Bias
A regulated power supply should be used to provide grid bias. The supply should be adjustable over a range of 10 to 100 volts. The supply should be swamped with a 100 ohm bleeder resistor. Alternately, regulated cathode bias may be applied. A conveniently packaged device to supply adjustable and regulated cathode bias is available from Varian. Contact Varian PGTP, Klystrode IOT Application Engineering for details.

Magnet Power Supply Regulation
Performance of the Klystrode IOT is relatively insensitive to magnet current. Magnet power supply regulation does not need to be better than ±10%. Ripple may be ±10%.

RF Arc Detector
An RF arc detector is provided as part of the CV-5000C circuit assembly for protection against external arcs in the output cavity. The detector is mounted on the output cavity, OC-550. The cadmium sulfide photo resistor sensor changes resistance value dependent on the amount of incident light level. With no light the resistance value is above 750K ohms. With an arc, or with the test lamp energized, the resistance value drops to less than 5K ohms. When this occurs, RF drive power and the beam voltage must be rapidly removed from the tube. However, the crowbar does not need to fire.

A test lamp is located near the arc detector to simulate an arc for test purposes. The test lamp is built into the output cavity, OC-550. It is sealed into the assembly housing with the photo detector. The assembly may be energized with 28 V at 1.5 mA.

Beam Power Supply with Aural only tube
For FM sound, the IOT in aural service may be operated from the same beam supply as the visual IOTs. Beam current may be adjusted to the value necessary for the required power output by changing the RF drive power.

Tube Protection
In the event of an internal tube arc, or an arc in the input cavity, a "crowbar" device must be used to instantly remove high voltage from the Klystrode IOT. In addition to that explained herein, Varian PGTP Application Bulletin #17 titled, "Fault Protection", is available upon request and contains considerable details on the subject.

OPERATING HAZARDS

Proper use and safe operating practices, with respect to high power vacuum tubes, are the responsibility of equipment manufacturers and users of such tubes. All persons who work with and are exposed to power tubes or equipment which utilizes such tubes must take precautions to protect themselves against possible serious bodily injury. Do not be careless around such products.

The operation of this tube may involve the following hazards, any of which, in the absence of safe operating practices and precautions, could result in serious harm to personnel. Please review the following hazards as well as the detailed operating hazards sheet enclosed with each tube, or request a copy from Varian.

High Voltage
Normal operating voltages can be deadly. Always remember that ***high voltage can kill!***

Low-Voltage, High-Current Circuits
Personal jewelry, such as rings, should not be worn when working with filament contacts or connectors as a short circuit can produce very high current and melting, resulting in severe burns.

X-Ray Radiation
Operating at high-voltages, IOTs are a potential source of dangerous X-rays and shielding may be required on all sides of the tube. An X-ray survey by an expert in this field of X-ray radiation may be required.

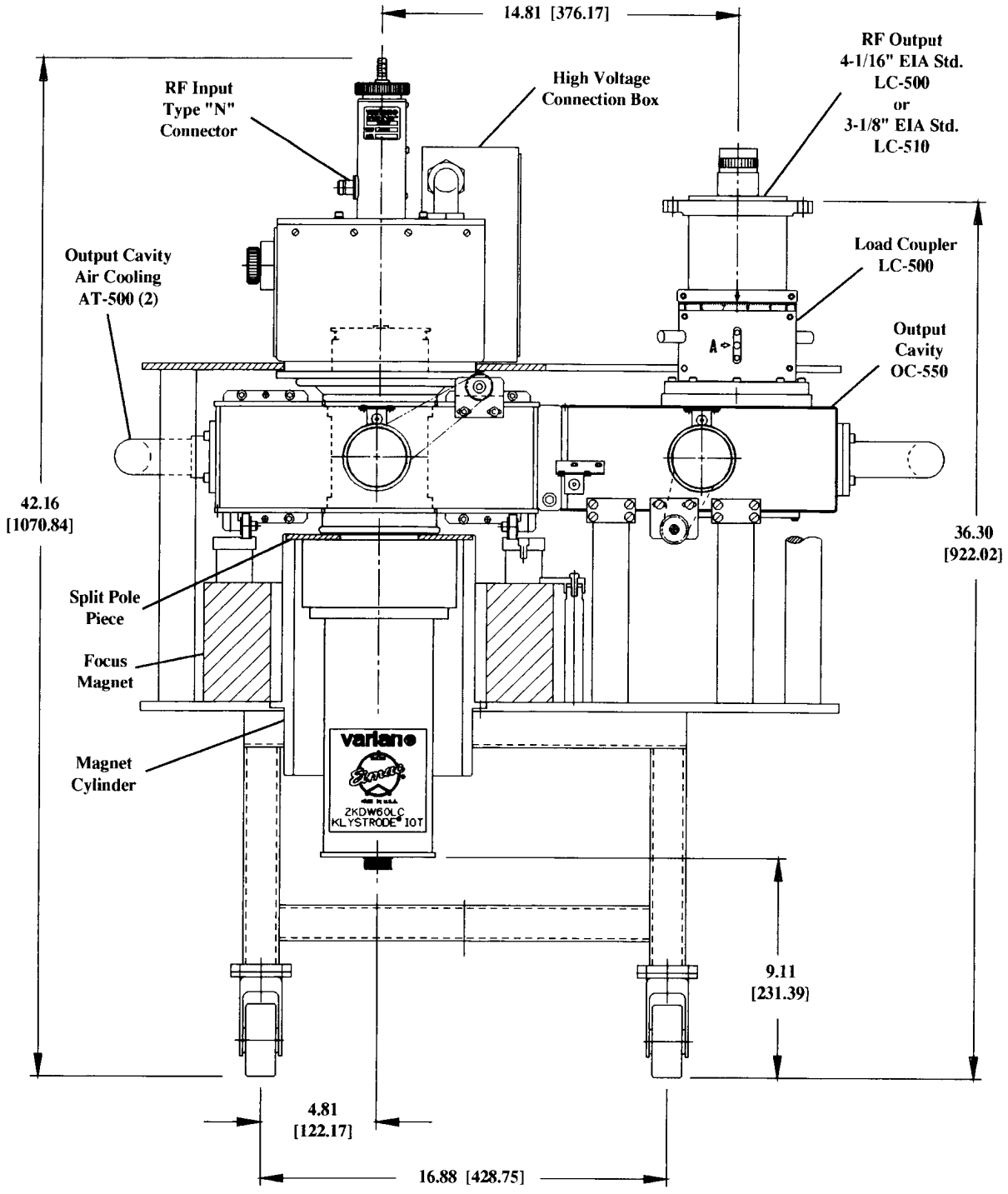
RF Radiation
Exposure to strong RF fields should be avoided, even at relatively low frequencies. The dangers of RF radiation are more severe at UHF and microwave frequencies and can cause serious bodily and eye injuries. Cardiac pacemakers may be affected.

Hot Surfaces
Surfaces of tubes can reach temperatures of several hundred degrees centigrade (°C) and cause serious burns if touched even after all power is removed from the tube.

Mechanical
The circuit assembly has been designed to occupy the minimum of floor space in the transmitter. As a result, the center of gravity is fairly high. Care is required when moving the circuit assembly dolly, with and without the IOT in the magnet assembly, in order to avoid overturning of the assembly and causing harm to personnel and equipment.

For More Information
Write or contact: Varian PGTP, Klystrode IOT Applications Engineering
301 Industrial Way, San Carlos, CA 94070, USA, Phone (415) 592-1221, FAX (415) 592-9988.

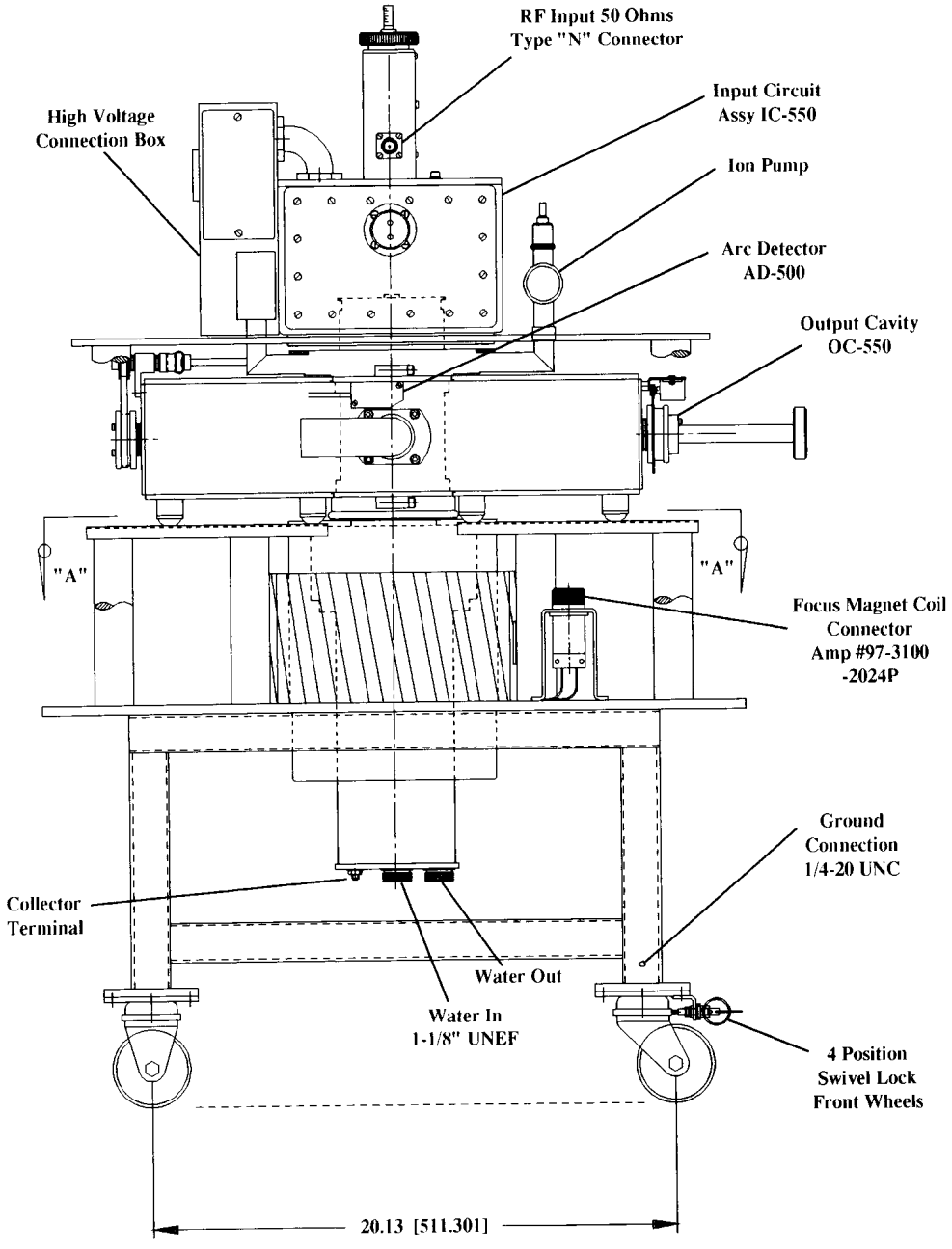
CV-5000C Circuit Assembly
(Shown with Klystrode® IOT Installed)



Front View

Figure 1

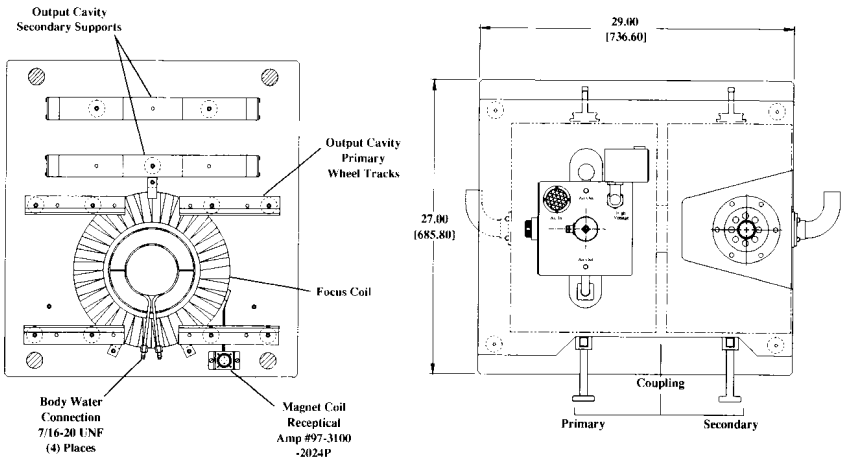
CV-5000C Circuit Assembly
(Shown with Klystrode® IOT Installed)



Left Side View

Figure 2

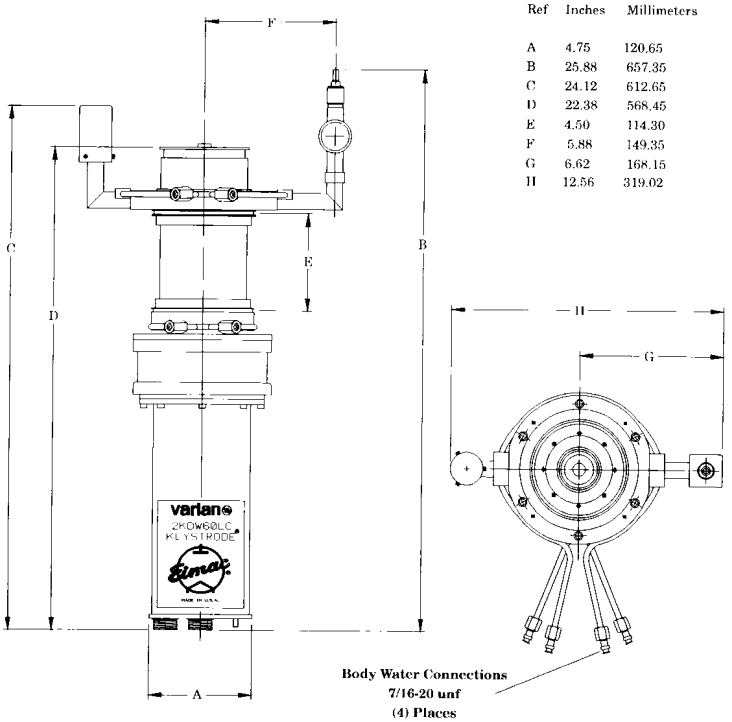
CV-5000C Circuit Assembly
(Shown with Klystrode® IOT Installed)



View "A-A" Top View

Figure 3

CV-5000C Circuit Assembly
(Shown with Klystrode® IOT Installed)



Ref	Inches	Millimeters
A	4.75	120.65
B	25.88	657.35
C	24.12	612.65
D	22.38	568.45
E	4.50	114.30
F	5.88	149.35
G	6.62	168.15
H	12.56	319.02

Figure 4

AD-500 Detector / Test Lamp

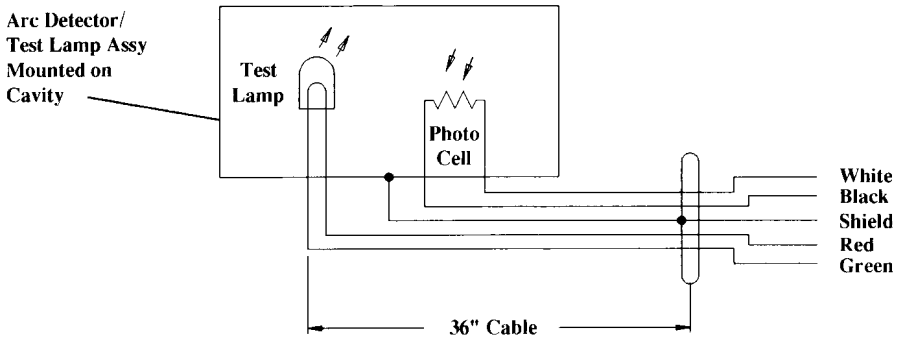


Figure 5

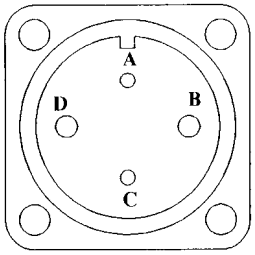
Focus Magnet Coil Receptical Connections

Focus Magnet Coil
Receptical Connections

Focus Magnet Coil Connector
Top View

Connections:

A) Interlock
B) Focus Coil Positive
C) Interlock
D) Focus Coil Negative



Amphenol Receptacle
P/N 97-3100A-2024P
Mates with Amphenol Plug
P/N 97-3106A-2024P

Pins A and C
May be connected internally
for use as an interlock.

Figure 6

Klystrode Tube Beam Voltage, Grid Bias and Heater Connections

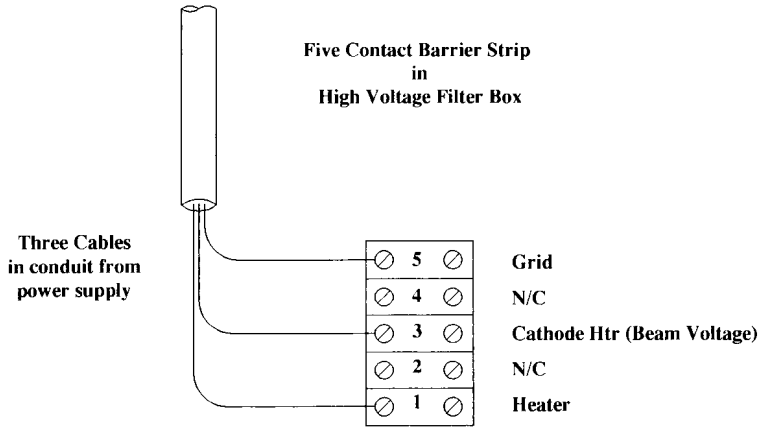
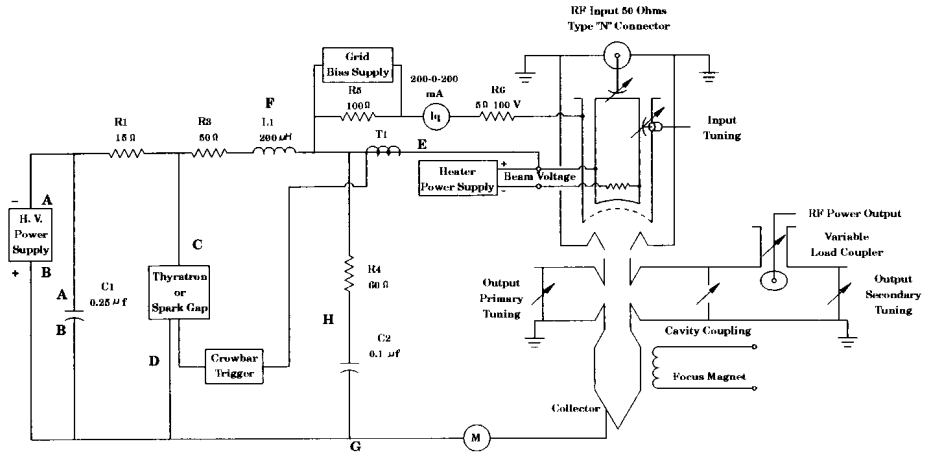


Figure 7

Typical Klystrode® IOT Transmitter Schematic Diagram



A) Lead length EHG should not exceed 5 feet.

B) If the sum of lead lengths AC+BD is more than 5 feet, add C2 so that the sum of AC+BD is less than 5 feet..

C) Crowbar consists of crowbar suitable trigger unit with thyratron or spark gap and overload sensor T1. Crowbar must limit arc energy in the tube to (4) joules.

D) R1 thru R4 are 300W non-inductive High Voltage resistors capable of holding off transient voltages in excess of the beam voltage.

E) Crowbar discharge currents can be close to a kiloamp. Care must be taken to avoid unwanted coupling of this transient into other circuits.

F) L1 is a high voltage inductor capable of withstanding transients in excess of the beam voltage without breakdown.

Figure 8

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power grid tube products
301 Industrial Way
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Fax: (415) 592-9988

EDB 2386/240 3/94 3M