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FINAL REPORT FOR
PIERCE-WIGGLER ELECTRON BEAM SYSTEM
FOR 250 GHz GYRO-BWO

CONTRACT B034261

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DISTRIBUTION OF

Final Report
for
Pierce-Wiggler Electron Beam System for 250 GHz Gyro-BWO

Contract B034261

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INTRODUCTION

This final report summarizes the design and performance of the VUW-8028 Pierce-Wiggler electron beam system, which can be used to power high frequency gyro-BWO's. The operator's manual for this gyro-BWO beamstick is included as appendix A.

Researchers at Lawrence Livermore National Laboratory (LLNL) are developing a gyro-BWO with a center frequency of 250 GHz, 6% bandwidth, and 1 kV peak output power. The gyro-BWO will be used to drive a free electron laser amplifier at LLNL. The electron beam requirements of the gyro-BWO application are:

- * Small beam size, .100 inch at 2500 gauss axial magnetic field
- * A large fraction of the electron energy in rotational velocity
- * Ability to vary the electrons' axial velocity easily, for electronic tuning
- * Low velocity spread i.e. little variation in the axial velocities of the electrons in the interaction region.

SPECIFICATIONS

To meet these requirements, Varian has designed and built a Pierce-Wiggler electron beam formation system consisting of a conventional Pierce gun and an integral solenoidal-helical magnetic field. The transverse helical (wiggler) field will be produced by permanent magnet strips fastened to a mandrel on the electron beam tunnel and converts part of the axial beam velocity to rotational velocity suitable for use in a 250 GHz gyro-BWO. Most gyrotron devices use a Magnetron Injection Gun (MIG) as an electron beam source; however, in this application a very small (<.030" diameter in the circuit) on-axis beam is required. Achieving such a small beam size and maintaining low velocity spread with a MIG would require unrealistic cathode loading. In addition, the Pierce-wiggler system offers the advantage of voltage tuning the gyro-BWO with minimum consequences to output power level (1).

To maximize the interaction efficiency, the electrons' velocity spread in the interaction circuit must be minimized. This requires an extremely laminar electron beam with high Brillouin number entering the wiggler. Table 1 lists the goal and actual performance parameters of the Pierce-Wiggler system:

TABLE 1

Parameter	Objective	Measured
Voltage	60-80 kV	^
Current	4-6.25 A	^
Perveance	.272 uperv	.272 uperv ^
Beam Size	100 mils	104 mils ^
Compression	16	25 ^
Cathode Loading	5 A/sq.cm.	3 A/sq.cm ^
Brillouin #	3.03	2.74 ^
Scalloping	<8 %	<4 % ^
Axial Field	2800 gauss max	3200 gauss
	2500 gauss over 6"	2500 gauss over 6"
Transverse Field	<0.2 %	<0.35 %
Helical Field	10-12 gauss	6-8 gauss
Weight	<50 lbs.	250 lbs.

* Full power tests will be conducted at MIT. Quoted values are for scaled operating parameters, 10 kV, 896 gauss axial field.

FEATURES

An engineering sketch of the Pierce-wiggler system is shown in Fig.1. To increase the experimental flexibility and simplify the operation of the system, a number of extra features have been designed into the system:

* Leads for the four pairs of wiggler coils are brought out to allow customized series-parallel connection and individual adjustment.

* A custom-built vacuum ball-valve with maximum o.d. of 1.48" will permit sliding the wiggler mandrel in and out of the wiggler solenoid for adjustment, even while the gun is attached to the rest of the gyro-BWO.

* A VacIon pump is built into the back of the gun and a VacIon power supply capable of battery operation will be provided. Hence, the VacIon pump can be operated while the gun is at high voltage. The VacIon pump will provide some vacuum pumping and monitor the gun vacuum.

* High speed vacuum pumping will be provided by two SAES sorption pumps built into the cathode support structure.

* A gun coil behind the cathode permits additional adjustment of the flux on the cathode, in order to optimize the beam focusing.

* A magnetic shield encases the wiggler solenoid in order to shield the beam from any stray magnetic fields and to isolate adjustments of the wiggler solenoid from adjustments in the interaction magnet.

These features will provide greater flexibility for insuring the optimum conditions for beam focusing, transmission, and interaction.

PERFORMANCE

Electron Gun

Where measured, the actual performance of the Pierce-wiggler gun is very close or better than the goal parameters. Figure 2 shows the beam diameter and scalloping measurements, taken on the Varian beam analyzer at 10 kV beam voltage and 896 gauss focusing field. The perveance was experimentally set at the goal value. The beam size at .104" diameter is very close to the goal value and the scalloping of 3.5 % is exceptionally small. Figure 3 shows the current density profile for the beam, with only slightly enhanced emission near the outer diameter, which is common for this size cathode. Figure 4 shows the electric field strength in the region of the electrodes. The peak field strength is about 140 kV/cm when 80 kV is applied to the cathode. Such high field strengths would probably cause arcing if the gun were to be operated continuously at these voltages. However, for 1-2 microsecond pulse lengths, arcing should not occur for field strengths up to 160 kV/cm. The anticipated operating voltages are 60 kV to 70 kV, which provides some additional safety margin.

Figure 5 shows a computer simulation of the electron trajectories for the electrode geometry and magnetic field profiles used in the gun with only "zero" order correction for thermal expansion effects. As expected, the simulation does not agree well with the measured parameters of the gun. Thermal expansion effects must be modeled accurately in order to attain good agreement between simulation and experiment. Time and resources were not available to complete accurate modeling of the electron trajectories including all thermal expansion effects.

Wiggler-Solenoid

Figure 6 shows the axial magnetic field for the wiggler electromagnet solenoid with all coils operating at maximum current of 50 A, and no upper polepiece insert (6" i.d.). The maximum field is well over 2800 gauss, and by adjusting the coil currents, the magnet will produce a 2500 gauss "flat" field over 6" length as shown in Figure 7. Figure 8 shows the transverse field for the magnet, which is <0.35% over the entire length of the solenoid, and <0.2 % over about half the length. One of the coils may have ended up slightly tilted during epoxy potting so as to cause the anomalous transverse field. Unfortunately, correcting such a discrepancy requires a major rebuild of the solenoid. Figures 9a and 9b show the helical field before the magnetic strips were exposed to the 2500 gauss axial field. Figure 10 shows the same strips after immersion in the 2500 gauss field. As expected, the strips become slightly demagnetized, but further exposure to 2500 gauss fields does not affect the strips. The amplitude variation of the helical field in the central region is probably due to inadequate fixturing for holding the strips in place once they are wound. The pitch for this wiggler is sufficiently small that adjacent windings attract each other strongly and tend to pull the strips "off pitch". Some spacers between the windings should improve the situation. The large amplitude "bumps" at the ends of the helical wiggler field are due to the small pitch-to-radius ratio for this wiggler. Several measures could be implemented to decrease these amplitude bumps by either 1) clever tapering of the helical magnetic field strength at the ends of the wiggler, or 2) increasing the wiggler pitch by decreasing the axial solenoidal magnetic field or increasing the beam voltage, or 3) decreasing the radius of the wiggler. Tapering the strength of the helical field is the most aesthetic option. Decreasing

the axial solenoidal field will decrease the Brillouin number of the electron beam and may adversely affect beam velocity spread; although, it will also produce a smaller electron beam and may improve beam transmission. Increasing the beam voltage will increase the risk of arcing. Decreasing the wiggler radius is an option since the beam tunnel wall is .375" thick; however, a smaller wiggler will not slide over the ball valve.

Magnetic Shielding and Focusing

The glaring discrepancy in Table 1 is the weight of the gun. The magnitude and consequences of the fringe magnetic field from the gyro-BWO interaction magnet were not fully appreciated in the early design. The original design incorporated some iron shielding to divert the fringing field of the interaction magnet; however, when the coil geometry of the interaction magnet was made available, the calculated amount of shielding to insure proper isolation of the Pierce-wiggler gun was over an order of magnitude greater than originally anticipated. Figure 11 shows the magnetic field calculation for the final shielding geometry. A large "field clamp" washer set off from the front face of the wiggler solenoid helps to divert some flux away from the solenoid shell and reduce magnetic saturation in the shell. The shield extending past the back of the cathode protects the cathode region from stray fields to insure proper focusing of the electron beam in the critical region close to the cathode. Figure 12 shows the calculated axial magnetic field profile for the Pierce-wiggler gun, including the fringing field of the interaction magnet. In the region near the cathode, the dashed line represents the magnetic field profile used on the beam tester that yielded very low beam ripple. The agreement between the two curves is very good. Figure 13 shows the measured magnetic field profile with the gun polepiece in place. Again, the agreement between the measured profile and the profile of the beam tester is very good.

CONCLUSION

The gyro-BWO experiments using the Pierce-wiggler beam system remain to be carried out. However, all measurements, calculations and simulations of the Pierce-wiggler gun indicate that it will satisfactorily meet requirements for powering a voltage tunable 250 GHz gyro-BWO.

- 1) Malcolm Caplan, Conference Digest, 12th Intl. Conf. on Infrared and MM waves, Dec. 1987, p. 276, IEEE Cat. #87CH2490-1

FIG. 1b Dimensions of the Pierce-Wigler Electron Beam System

FIG. 2. Beam tester measurements of diameter and ripple at scaled parameters: 10 kV beam voltage, 896 gauss focusing field. Beam diameter: .104", Beam ripple: < 3.5%.

FIG. 3 3-D representation of beam current density as a function of radius at an axial position of 1.70" from the cathode. The beam radius and current density are very uniform.

FIG.4. High Field Region of the Electric Field Strength. Although the field strength is high, up to 160 kV/cm should be tolerable for 1-2 μ second pulses. The high voltage seal ceramic experiences little stress, 25-30 kV/cm.

Simulation

Beam Analyzer

FIG. 5 Simulations of electrostatic beam trajectories compared to measurements on the beam analyzer. Significant additional effort would be required to accurately model the beam analyzer results.

Fig. 5b Simulation of electron trajectories (above) compared to beam analyzer measurements (below). Further work would be required to improve the modeling.

VYW--8028W Gyro--BWO Beamstick Magnet

FIG. 6 Maximum Field in the region of minimum with 10" field poles, at both ends.

H. Anderson
 2/11/51
 9/9/51

C8028A.0NE

VYW-B02BW SOLENOID: COL. POLE PIECE, 1.3" DIA GUN POLE PIECE, IS=38.5A 1-NOV-88

BB02BA.TRV

VYW-B02BW SOLENOID: IS=38.5A 30-SEP-88

FIG. 8 Transverse field of the wiggler solenoid is close to the goal of .2%
The data becomes "noisy" below 1 inch axial position because both the
axial field and the transverse field become very small.

TRANSVERSE FIELD PERCENTAGE

DU1: A8028A.TRV

VYW-8028 WIGGLER COIL: AFTER EXPOSURE TO IS=38.5A (5 MIN.)

FIG. 9a Transverse field of the wiggler measured 90 degrees apart azimuthally, showing circular polarization.

AXIAL MAGNETIC FIELD

CB028A.TRV
VYW-8028 WIGGLER COIL 3-NOV-88

FIG. 9b Amplitude (solid line) and direction (dotted line) of the transverse field of the wiggler.

FIG. 10 Transverse field of the wiggler after exposure to 2800 Gauss axial field.

A8028A.TRV

VYW-8028 WIGGLER COIL: AFTER EXPOSURE TO IS=38.5A (5 MIN.)

FIG. 11 Magnetic shielding configuration showing field lines (above) and magnitude contours (below).

VUW-8028W WIGGLER SOLENOID WITH SUPERCON

GYROA.FLD
MAGNETIC FIELD

FIG. 13 The measured field profile is a close match to the profile used on the beam analyzer.

OPERATOR'S MANUAL FOR THE
VUV-8028 PIERCE-WIGGLER ELECTRON BEAM SYSTEM

87-800 1233

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OPERATOR'S MANUAL FOR THE VUV-8028
PIERCE-WIGGLER ELECTRON BEAM SYSTEM (BEAMSTICK)

PLEASE READ THE WARNINGS AND CAUTIONS WHICH FOLLOW CAREFULLY.

Refer to Fig. 1 to become familiar with the main components of the Pierce-wiggler beamstick.

WARNINGS PROVIDE INFORMATION TO PROTECT THE HEALTH AND SAFETY OF THE OPERATOR AND/OR OTHER PERSONNEL WHO INTERACT WITH THE EQUIPMENT. FAILURE TO HEED WARNINGS MAY LEAD TO SEVERE INJURY OR DEATH.

CAUTIONS PROVIDE INFORMATION TO PREVENT THE EQUIPMENT FROM BEING EXPOSED TO DAMAGING OPERATING CONDITIONS. FAILURE TO HEED CAUTIONS MAY LEAD TO MALFUNCTION OR DESTRUCTION OF THE EQUIPMENT.

WARNING! ELECTRICAL SHOCK HAZARD! This equipment utilizes high voltage power from three distinct power sources, any one of which is potentially lethal. The solenoid magnet is energized with voltages as high as 70 volts, the VacIon power supply operates at 3 kV, and the electron gun operates at voltages as high as 80 kV. Also note that the VacIon pump floats at the gun cathode potential. Extreme prudence and diligence must be exercised to insure proper insulation, grounding and operation of the beamstick, in order to prevent injury or death from electric shock.

WARNING! HIGH MAGNETIC FIELD; PACEMAKER HAZARD! The wiggler solenoid produces magnetic fields up to 3.2 KG. Proper precautions should be taken by those with pacemakers. Ferrous materials should be kept at least 6" away from the wiggler solenoid and its shielding.

WARNING! CAUTION! HIGH INDUCTANCE LOAD! Do not interrupt the wiggler solenoid or gun coil current suddenly. Very high voltages will be produced that will present an electric shock hazard and may damage the magnet coils.

WARNING! CAUTION! ELECTRICALLY "FLOATING" BALL IN THE VACUUM BALL-VALVE. If the electron gun is operated with the ball-valve closed, the ball will charge up to the cathode potential, which will present a potential electric shock hazard, and may cause arcing and damage to the vacuum seal material in the valve. Once the beamstick is installed in the experimental system, attach a ground lead to the slot head screw used to open and close the valve. This will ground the ball and prevent it from charging up should the gun be operated with the ball closed.

WARNING! X-RAY SOURCE! Under normal operating conditions, the beamstick will produce x-rays. Normally, the x-rays are absorbed by the metal walls of the beamstick and experimental system. However, the experimental system can be configured to release harmful amounts of

[illegible]

x-rays. Proper precautions should be taken by the operator to monitor and prevent exposure to x-radiation. The operator is referred to Nuclear Regulatory Commission regulation 10CFR20 for an explanation and description of the legal exposure standards for x-rays.

WARNING! HEAVY, AWKWARD EQUIPMENT! The VUV-8028 equipment weighs approximately 250 pounds including the floating polepieces. Use the proper lifting equipment to prevent personal injury and damage to the equipment.

CAUTION! FRAGILE EQUIPMENT! The oil insulating box, the VacIon pump and the electron gun are mechanically fragile. Do not attempt to lift or move the beamstick by holding on to these parts of the equipment.

CAUTION! POTENTIAL SATURATION OF IRON SHIELDING! Always energize the wiggler solenoid magnet before energizing the interaction magnet. This will prevent the iron shielding around the wiggler solenoid from saturating and producing hysteresis affects which may influence the magnetic focusing of the electron beam.

CAUTION! ELECTRIC INSULATING OIL REQUIRED! Make sure the oil insulating box and cathode shield are filled with electric insulating oil before applying voltage to the gun. Without oil, arcing damage and electric shock hazard may result.

CAUTION! WATER COOLING REQUIRED! The wiggler solenoid requires 1.6 gallons per minute minimum water flow. Failure to provide cooling may lead to overheating of the magnet and damage to the coils. If any stagnant water is left in the cooling channels, a steam explosion may be generated.

1.0 INTRODUCTION

This manual describes procedures for processing, handling, installing and operating an electron beam system designed for use with cyclotron resonance maser devices. Expected performance for the electron gun is also described.

The design values for the gun operating parameters are summarized in Table 1.

Table 1
Summary of Gun Operating Parameters

Beam Voltage	60-80 kV pulsed
Beam Current	6.2 A max pulsed
Heater Voltage	10.25 volts AC approx.
Heater Current	3.25 A AC approx.
Duty Factor	1x10 ⁻² max.
Operating Vacuum	10 ⁻⁷ torr typical 10 ⁻⁶ torr for brief periods
Cooling	Water cooling of wiggler solenoid 1.6 GPM min.

(Entire gun to operate immersed in insulating oil).

2.0 FACTORY PROCESSING

A number of processing and testing procedures are planned for the initial assembly of the electron beam system. These include a cathode temperature test, vacuum processing, hi-potting, getter activation, cathode activation, emission test, and a vacuum integrity test.

2.1 Cathode Temperature Test

The purpose of this test is to determine cathode temperature as a function of heater voltage and current. This test can best be performed during the construction phase when the entire central portion of the gun is completed but has not yet been welded to the ceramic insulators and anode. At this stage of the construction, the central portion will be placed in a dummy vacuum system which will simulate the cooling effects of the anode, allowing pyrometer measurement of cathode temperature. The measured data of cathode temperature versus heater voltage and current will be shipped with the gun.

2.2 Vacuum Processing

The final assembly of the gun will be completed after the cathode temperature test. The assembled gun and an attached 2 l/s VacIon appendage pump will then be evacuated and baked at approximately 150 degrees Celsius. This relatively low temperature is dictated by the safe limits for the seals in the ball valve. After

bakeout, the getters will be activated and the cathode will be heated to normal operating temperature to remove excess gas. The gun assembly will then be valved off from the processing station with the appendage pump being left to monitor the vacuum in the gun assembly. After valve off, the appendage pump should maintain the vacuum at 2×10^{-7} torr or less, corresponding to a pump current of 2 uA or less.

2.3 Getter Activation

WARNING: The base of the electron gun becomes very hot (100-150 degrees C) during getter activation.

The cathode should be cold during getter activation. The getters are activated by heating them to 700-900 degrees Celsius, for 10-20 minutes. Heating is accomplished by passing 10.5 A to 11.0 A ac through the getter heater elements. Figure 2 shows a schematic diagram of the electrical connections for the getters. The getters can be activated individually or simultaneously. To activate the getters individually, current should run from the particular getter input to common. To activate the getters simultaneously, the current should run from one getter input to the other. Activating the getters simultaneously is desirable, so as to avoid a situation of the outgassing due to the getter that is being activated causing the cool getter to become saturated with gas. Manufacturer's data for the getters is provided in appendix A. The manufacturer's data indicates 11.5 amps current to attain 800 degrees Celsius; however, that data was taken in a large glass system. The environment around the getters in the gun acts as an effective heat and radiation shield, hence the heating current required has been decreased accordingly. The current to the getter heater elements should be raised slowly, so the VacIon pump is not swamped. As the heater power to the getters is increased, there is an initial gas burst as surfaces which are heated directly and indirectly outgas. After this initial gas burst, which can be as high as 2×10^{-3} torr, the pressure should decrease steadily.

2.4 Hi-Potting

After vacuum processing is completed, the gun assembly will be hi-potted with a high-impedance dc supply with the cathode cold and with no magnetic fields applied to the gun. The ceramic between the cathode and anode will be hi-potted until the leakage current is less than 100 uA with 48 kV applied, corresponding to peak electric fields of approximately 85 kV/cm. The polarity of the voltages will correspond to the normal operating polarity. The leakage current at the end of hi-potting will be recorded and included with the shipped data.

2.5 Cathode Activation

The anode will be tied to ground and a low dc voltage (approx. 500 Vdc) will be applied to the cathode. Heater power will be set at the nominal operating point. The beam current and base pressure in

Fig.2 Electrical Schematic of Getter and Gun Heaters.

the gun will be recorded until the cathode becomes activated and beam interception degasses the gun anode. The beam power will be limited to 10 W.

2.6 Vacuum Test

The gun assembly will be allowed to cool, and a base pressure reading will be made using the appendage pump after emission measurements have been completed. The pump voltage will then be turned off for 24 hours. After this period of time, the pump voltage will again be applied, and the appendage pump should bring the vacuum down to 2×10^{-7} torr or less to correspond with a pump current of 2 uA or less.

3.0 HANDLING

The factory-tested electron gun will be shipped with the appendage pump attached, which facilitates periodic checks of the internal vacuum. The gun pressure should be checked periodically. Continual increases in pressure would indicate a possible vacuum leak. Small leaks, if they develop, can often be localized and repaired without completely reprocessing the gun. A normal gun should show negligible pressure changes with time for periods of several years.

The electron gun may be stored in any reasonable environment. Dust, high humidity, and corrosive atmospheres should be avoided. High magnetic fields should be avoided also, to prevent saturation of the iron shroud around the electromagnet.

4.0 INSTALLATION

Unpacking - Remove the styrofoam cushion from around the VacIon pump tubulation before operating the gun. Refer to disassembly instructions 1&2 below.

Disassembly - It may prove desirable to disassemble the Pierce-wiggler system in order to conduct in-situ magnetic field measurements and vacuum processing of the electron gun. The following procedure for disassembling the Pierce-wiggler beam system is recommended; cf. Fig. 1:

- 1) Verify that all power to the system is off. Disconnect any power input banana plugs from the top of the Oil Insulation Box. Unscrew the four Phillips head screws which hold the top of the Oil Insulation Box in place. Gently lift off the top of the Oil Insulation Box, and disconnect the banana plugs coming from the Gun and Gun Coil. Remove the top of the Oil Insulation Box completely.

- 2) Drain any oil from the Oil Insulation Box. Gently disconnect the VacIon power input lead from the VacIon pump. Avoid putting any excess

torque on the tubulation which connects the VacIon pump to the gun. Carefully remove the shielded magnet assembly from around the VacIon pump. If this is the initial unpacking of the system, remove the styrofoam cushion from around the tubulation which connects the VacIon pump to the gun.

3) If the 20" diameter floating polepiece is attached to the system, unbolt the floating polepiece from the Pierce-wiggler system or unbolt the Pierce-wiggler system from the floating polepiece, whichever is appropriate.

4) Unscrew the six 10-32 socket head bolts which hold the Split Centering Insert in place. Remove the Split Centering Insert and the Split Upper Polepiece.

5) To remove the Wiggler, find the black braided nylon cord in the bore of the Solenoid Magnet, and gently pull on the cord to pull out the Wiggler.

6) Orient the remaining pieces of the Pierce-wiggler assembly with the Vacuum Valve down and the Oil Insulation Box up. Remove the teflon Lead Separator, which separates the gun coil leads from the heater and getter leads, by pulling it out of the hole, cf. Fig. 3. It comes out with difficulty, but the internal lip will deform enough to allow the Lead Separator to slip out.

7) Unscrew the six 10-32 socket head bolts that hold the Oil Insulation Box in place and remove the Oil Insulation Box.

8) Unscrew the six 1/4-20 socket head bolts that hold the Cathode Magnetic Shield in place and remove the Cathode Magnetic Shield.

9) Unscrew the six 10-32 socket head bolts that hold the Gun Coil and Gun in place and remove the Gun Coil.

10) The Gun can be removed from the Wiggler Solenoid once the Gun Coil is removed. The Gun is held in place by only a (tight) slip fit with the magnet bore.

This completes the disassembly of the Pierce-wiggler system. The Wiggler Solenoid end plates can be unbolted and removed to expose the solenoid coils; however, removing the end plates and shell will change the alignment of the solenoid coils. We recommend that the Wiggler Solenoid be returned to Varian if repairs seem warranted.

Reassembly of the Pierce-wiggler system is carried out by following the disassembly steps in reverse order.

The electron gun should be stored with internal high vacuum until an experimental device is ready to receive the gun. The system can be connected to the experimental device using the Conflat flange on the valve to mate with a similar flange on the device. For the proper alignment of the gun with the rest of the vacuum system, the vacuum

Fig.3 Removing the Lead Separator

valve output flange should be aligned with the customer's flange. The established Varian procedure for assembling Conflat flanges should be followed closely. Once this connection is made, the internal volume of the customer's device should be evacuated to as low a pressure as possible. The VacIon pump for the gun should be energized, and the internal volume of the gun pumped to as low a pressure as possible also.

Once both sides of the ball valve are at low pressure, the vacuum ball valve can be opened. The vacuum ball valve goes from fully closed to fully open in $1/4$ turn. Rotation can be either clockwise or counter-clockwise. The valve is fully closed when the slot in the valve stem is perpendicular to the axis of the beam tunnel and points to the word CLOSED imprinted on the valve. The valve is fully open when the slot in the valve stem is parallel to the axis of the beam tunnel. Seal life for the vacuum ball valve will be maximized if the valve is opened and closed by turning the valve in opposite directions. For example, if the valve is closed, it can be opened by turning the valve $1/4$ turn COUNTER-CLOCKWISE. Seal life will be maximized if the valve is reclosed by turning the valve $1/4$ turn CLOCKWISE, although continuing to turn the valve $1/4$ counter-clockwise will close the valve just as effectively in the short run (dozens of cycles). Initially opening the valve by turning counter-clockwise is not sacrosanct; a clockwise turn would be just as effective. However, in that case, closing the valve by turning counter-clockwise would maximize seal life for the valve. The valve is predicted to be good for dozens of cycles independently of how it is opened or closed.

CAUTION! WARNING! The ball and stem of the valve are electrically insulated by the seals, and hence "float" electrically. If the gun were operated with the valve closed, the ball and stem would charge up to the cathode potential causing arcing, possible damage to the valve, and a possible electric shock hazard for personnel. We recommend that a ground strap be clipped to the stem of the ball valve whenever possible; whether the valve is open or closed.

5.0 OPERATION

CAUTION! The Wiggler-Solenoid magnetic shell is susceptible to saturation and hysteresis effects with possible adverse effects on the electron beam focusing, if the interaction (high field) magnet is energized before the Wiggler Solenoid. Always energize the Wiggler Solenoid before the interaction magnet in order to minimize the chance of saturation of the Wiggler-Solenoid magnetic shell.

When a system pressure of 10^{-8} to 10^{-7} torr is achieved, it should be possible to begin to apply heater power. The gun should be immersed in oil. The heater voltage should be gradually increased, keeping the vacuum as low as practical but not exceeding 10^{-6} torr. The cathode can be operated at temperature with the vacuum at 2×10^{-7} torr or better. A pyrometer measurement of the cathode registered 1050 degrees Celsius at a heater power of 10.25 Vac and 3.25 Aac; however, space-charge limited operation was achieved in bakeout with a heater

power of only 9.5 Vac and 3.0 Aac. Cathode life is maximized by operating at the lowest heater power which gives fully space-charge limited emission.

Normally, the gun can be operated with any combination of heater or beam voltages at the design values or lower without damage. For example, with the cathode cold, high voltages can be applied without damage. If high beam powers are developed it is essential that magnetic field be applied to direct the beam to elements that have adequate cooling. Operating the wiggler solenoid at 38.25 Adc produces approximately 2500 Gauss magnetic field to focus and guide the electron beam properly.

CAUTION! The thermal capabilities of the gun elements such as the anode are on the order of 10 W average power. Exceeding this value could produce damage.

In some cases, certain combinations of internal pressure and applied high voltage and magnetic field can give rise to plasma discharges. These can be detrimental either with respect to heating or sputtering of material on insulators. These discharges can occur if the cathode is either hot or cold. They may be detected by abnormal currents or pressure changes. In general, operation with this kind of discharge should be avoided.

If difficulty is experienced in applying high voltages, it may be necessary to repeat the hi-potting procedure described in Section 2.4. This should be done with the cathode cold using a power supply with the capability of gradually increasing the energy delivered to the elements being hi-potted.

To predict the performance of the gun in operation tests were performed on a beam analyzer. Figure 4 shows the measured beam envelope for scaled voltages of 10 kV on the cathode and 896 Gauss focusing field. Figure 5 shows the focusing field in the region of the cathode produced by the wiggler solenoid compared to the field profile used in the beam analyzer tests. Figure 6 shows the axial solenoidal field at 38.5 Adc charging current. Figures 7-8 show the field in the region of the cathode due to each coil individually.

Figure 9 shows the magnetic field of the wiggler. The dark line shows the field amplitude and the dotted line shows the direction of the field. The wiggler produces approximately 7.5 Gauss helical field for four pitches and the equivalent of one pitch with about 24 Gauss. At resonance, this configuration should produce an alpha of about .075 to .12 coming out of the wiggler, which would correspond to an alpha of about .4 to .9 at an interaction field of 65 KG.

A specification for the wiggler solenoid is presented in appendix B. The operation manual for the VacIon power supply is included in appendix C. The Test Performance Sheet for S/N 001 is presented in appendix D.

6/2
12

Fig 4. Beam analyzer measurements of the VUW-8028 gun.
The effective beam size of $.104\phi$ is very close to the specified size, and the scalloping of 3.5% is extraordinarily low.

C8250F.DAT
XK-8250, DIODE GUN

Code XK-8250 __DIODE__

GRID: Bias //

Type T-1 R-4a

IRON ID= 1.2 INCHES

Date 9-JUN-88

IRON "0" REF.=1.002

Time 4:15 PM

Solenoid: Is 14.4/ 10.3 A.

HEATER: Eh 12.22 V.

Gun Coll: Ig = 2.5 AMP.

Ih 3.67 AMPS.

Delta K 0.651

CATHODE: Ek 10.0 KV

Zero ref. 1.151

Ik 272 MA.

TARGET: Type MOLY 0.3" DIA.

uPerv .272

Pinhole diam. 0.0018

Pressure: 8X10-8

Fulser: ETM-FAST-SPEED

C8028A.0NE

VYW-8028W SOLENOID: COL. POLE PIECE, 1.3" DIA GUN POLE PIECE, IS=38.5A 1-NOV-88

C8028D.ONE

VYW-8028W SOLENOID: 1ST COIL. IS=38.5A 2-MOV-88

Fig.7 Axial field in the region of the cathode due to each coil in the wiggler solenoid. Each coil is charged to 38.5A dc, all other coils off

+ = Same polarity as I_s .

CB028B.ONE

VYW-8028W SOLENOID: 1.3" DIA. POLE PIECE, $I_S=0$, $I_G=+5.0A$ 1-NOV-88

CB028C.ONE: VYW-8028W SOLENOID: 1.3" DIA. POLE PIECE, $I_S=0$, $I_G=+10.0A$ 1-NOV-88

Fig.8 Axial field in the region of the cathode, due to the gun coil alone. When the red lead of the gun coil has the same polarity as the red leads of the wiggler solenoid coils then the gun coil field aids the wiggler solenoid field.

Fig. 9 Amplitude and direction of the wiggler field. The direction oscillates periodically, showing the helical nature of the field

APPENDIX A: SAES GETTER DATA

St 171 NON-EVAPORABLE MINIPUMP GETTER DEVICES

Technical Data Relating to:

- **Gettering Capacity**
- **H₂ Equilibrium Pressure**
- **Activation Conditions**
- **Current Versus Temperature Relationship for St 171 Getters with Internal Heaters**
- **Technical Drawings for St 171 with Internal Heaters**

Gettering Capacities of St171 Getters After First Activation

Code N.	Type of Getter	CO (cc Torr/Getters)		N ₂ (cc Torr/Getters)		O ₂ (cc Torr/Getters)		H ₂ (cc Torr/Getters)	
		25°C	400°C	25°C	400°C	25°C	400°C	25 + 400°C	
B20351	St 171/LMI/ 1.5- 7 / 10	1	20	0.5	10	10	100	Above	150
B20310	St 171/ NI/ 3 - 3 /200 C	1	20	0.5	10	10	100	"	150
B20301	St 171/LMI/ 4 - 7 /200	5	100	2.5	50	50	500	"	1,100
B20701	St 171/ NI/ 7 - 6 /150 C	20	400	10	200	200	2,000	"	2,000
B20920	St 171/ NI/ 9.5- 7.5/250 C	25	500	12	250	250	2,500	"	5,000
B20950	St 171/ NI/10 -10 /300 C	80	1,600	40	800	800	8,000	"	12,500
B21700	St 171/ NI/20 -10 /650 C	180	3,600	90	1,800	1,800	24,000	"	37,500
<hr/>									
B30800	St 171/P5/ 5- 6 /150	1.5	30	0.7	15	15	150	"	250
B10500	St 171/OL/ 5- 3 /150	1.5	30	0.7	15	15	150	"	250
B01100	St 171/OU/11- 6.0/200	2.5	50	1.2	25	25	250	"	500
B01103	St 171/OU/11- 6.0/200 T 3	2.5	50	1.2	25	25	250	"	500
B04000	St 171/OU/45-33 /950	200	4,000	100	2,000	2,000	20,000	"	35,000
B05000	St 171/OU/50-33 /700	300	6,000	150	3,000	3,000	30,000	"	50,000

NOTE : 1) - Gettering capacities for CO, N₂ and O₂ have been determined at constant pressure of 3×10^{-6} torr whereas that for H₂ at constant pressure of 6×10^{-6} torr. Capacity for CO, N₂, O₂ is taken as capacity when pumping speed has reached 1% of initial measured speed.

2) - Gettering capacity for CO₂ is practically same as for CO.

3) - Gettering capacity for H₂O at room temperature is about 5 times higher than that for CO at room temperature.

St 171 NON-EVAPORABLE MINIPUMP GETTER DEVICES

St 171 GETTERING CHARACTERISTICS FOR CO AT VARIOUS TEMPERATURES

H₂ EQUILIBRIUM PRESSURE OF ST 171 AS A FUNCTION

OF SORBED H₂ AT VARIOUS TEMPERATURE

NOTE : The equilibrium isotherms for St 171 obey the following equation:

$$\log P = 3.6 + \log q^2 - \frac{5,200}{T}$$

where : P = equilibrium pressure of Hydrogen
in Torr

q = quantity of Hydrogen sorbed in
cm³ Torr/mg getter

T = Absolute temperature (°K)

ACTIVATION CONDITIONS FOR ST 171 NON-
EVAPORABLE MINI-PUMP GETTERS

During the first exposure to air of the surface of the St 171 getters a very thin but compact film of oxides and nitrides is formed.

This film protects the material from further contamination.

In order to make the getter active it is necessary to diffuse the protective layer into the bulk.

This is achieved by a heating process called ACTIVATION.

The activation process must be carried out in a vacuum of 10^{-3} Torr or better for combination of time and temperature sufficient to remove the surface oxide and nitride layer.

In the following figure are reported activation efficiencies available using different time-temperature combinations.

As shown in this figure the possible combinations are extremely numerous and moreover different time-temperature combinations can be used to achieve similar activation efficiencies.

NOTE

A 100% activation efficiency corresponds to the ideal activation process giving the optimum gettering performances of a St 171 non-evaporable getter.

AUTHOR

ES/11

Checked

S

Date

Sheet

1

EFFICIENCY OF ACTIVATION OF St171

SI 171 NON-EVAPORABLE MINIPUMP
GETTER DEVICES

**CURRENT VERSUS TEMPERATURE RELATIONSHIP
FOR**

SAES® St 171® NON-EVAPORABLE POROUS GETTERS.*

Traditional non-evaporable getter materials show optimum gettering performances when operated at high temperature (e.g. 300-600°C) while at lower temperature their performances become in some cases insufficient.

Non-evaporable porous getters have been developed just to fulfill this technical demand.

Since at low temperatures only the surface is responsible for gas sorption this objective has been reached by maximizing surface and porosity of the getter structure.

The St 171 non-evaporable porous getters use fine zirconium powder as the active material. It is sintered at high temperature mixed with graphite powder using proprietary techniques which confer not only the required characteristics of high porosity and large surface but also a good mechanical strength.

In case of use of St 171 getters at high temperature (e.g. above 300°C) gas sorption is not only limited to the surface of the zirconium grains but diffusion into the bulk takes place thus resulting in much better gettering performances.

* Manufactured by SAES GETTERS S.p.A. under licence from Siemens A.G.

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Activation

The St 171 material, like all other non-evaporable getter materials, must be activated to enable it to function as a getter. The activation must be carried out under vacuum, at a temperature and for a time, sufficient to remove from the surface of the getter material the thin protective layer formed at room temperature during the first exposure to the air at the end of manufacturing process.

The full activation of St 171 getter material can be obtained by heating the getter under a vacuum better than 10^{-3} torr at, for example, 900°C for 10 minutes. However, other combinations of temperatures and times are possible, which also result in a complete activation.

When only a limited activation time or a low heating temperature are possible, reasonable sorption characteristics can be achieved by a partial activation of the getter.

Fig. 1 is a comparison of the getter efficiency (expressed as a percentage of the initial pumping speed of a fully activated getter) after various activation conditions.

Fig. 1 - EFFICIENCY OF ACTIVATION OF St 171

Activation can also be achieved by an intermittent heating of the gettering devices provided the cumulative heating time is the same as that of a continuous activation. In this way localized overheating of nearby tube parts can be minimized.

Non-Evaporable Porous Getters

**saes
getters**

St 171

During the activation process of St 171 getters the gas pressure within the device may be observed to rise. This pressure is due to the release of small quantities of hydrogen which, in any case, can be quickly repumped by the getter when it cools down. Traces of other gases may also be noticed during first activation. These can originate from local heating of the areas surrounding the getter during the activation. Another source can be the gases physisorbed on the surface of the getter itself.

Reactivation

The pumping speed of a St 171 getter tends to decrease with the progressive sorption of gaseous species until it eventually can become too low to cope with the degassing rate of the device in which the getter is mounted.

By a new heating treatment, called reactivation, it is possible to restore the pumping efficiency of the getter. The reactivation is performed by heating the St 171 material at a temperature slightly below or equal to the activation temperature (e.g. 800-900°C). The time necessary is usually shorter (e.g. about 5 minutes).

The St 171 getter can be reactivated several times.

Reactivation can be performed whenever necessary and can be a useful means to recover a good vacuum during the life of a device.

Sorption characteristics

Active gases such as CO, CO₂, N₂, and O₂ are sorbed by St 171 getters forming very stable chemical compounds. Their sorption is therefore irreversible. While at room temperature these gases are sorbed only on the surface, at higher temperatures they diffuse into the bulk.

Therefore gettering characteristics for these gases considerably increase by increasing the sorption temperature.

Sorption speeds for CO at different temperature are shown in Fig. 2.

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Behaviour of St 171 in tube processing

Processing of devices is sometimes carried out in the temperature range of 300-500°C. In these conditions the St 171 getter can withstand very severe environmental conditions without being appreciably contaminated.

Use of St 171 Getters as a mini-pump

When properly activated and kept at temperatures between 400 and 500°C the St 171 getters can also be conveniently used as a mini-pump during the processing.

Reasons which may justify this use of St 171 getters are:

- The pumping speed available through the getter is higher or at least comparable with that available through the pumping tubulation. This allows either a shortening of the processing time or a better vacuum in the device.
- Final steps of the processing and the ageing of the device can be performed with the tube already removed from the main pumping system, the gases released being sorbed by the St 171 getter.

Fig. 6 - SORPTION CHARACTERISTICS OF A St 171/HI/16-10/300 C GETTER AT 400°C

saes getters

10) S1171/OU/11-6.B/200-TK 7.5

INDICATIVE TEMPERATURE-CURRENT CURVES FOR RESISTANCE HEATING Sr171 GETTERS

A new non-evaporable gettering material (NEG), called St172, has been developed by SAES and is now available in addition to the well known porous bulk getters type St171[®] (zirconium-graphite) produced by SAES since 1972.

The St172 material has a porous sintered structure based on a mixture of Zr + St707 alloy (Zr-V-Fe). This alloy is characterized by a high diffusivity of the sorbed species. The getter mass obtained as a result of a proprietary sintering process has a large surface area and a high porosity and presents excellent mechanical strength and coherence.

Thus the three requirements to optimize a getter device i.e. high diffusivity, large surface area and high porosity are combined together in St172 getters.

This results in the most advanced NEG available today.

MAIN CHARACTERISTICS OF THE St172 GETTER MATERIAL

a) low activation temperature

The commonly available non-evaporable getter materials presently require a relatively high activation temperature to have the maximum degree of efficiency. This temperature is generally up to 700-900°C and can cause some problems in certain applications.

One of the main advantages of the new material is the good degree of efficiency even after low temperature activation in the range of 400-500°C for a period of between 2 to 10 minutes. The benefits that can be obtained with this lower temperature of activation are:

- lower temperatures in the vicinity of the getter during activation therefore less risk of damage to other components by heat radiation
- less outgassing of nearby walls or components
- less robust feed-through required
- less activation current thus reducing the energy requirements.

Obviously if no low activation temperature limitations exist the full potential gettering ability can be exploited by activating in the range of 800-900°C for the above indicated period of time.

b) operation at low temperature

Besides the applications at room temperature, for which the St172 getters appear particularly suitable, it is also very important to mention that the St172 getter develops significant pumping characteristics already when operated in the 150-300°C range instead of 300-400°C as in the case of other similar getters such as the St171 series.

c) high compactness

Another important innovative aspect of the St172 getter material is its excellent mechanical strength and compactness. These characteristics make the getter particularly suitable in those applications where it is absolutely necessary to avoid loose particles.

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d) can be used as an in-situ mini-pump

As the getter activation temperature in some cases could be in the same range as the usual tube processing temperature, the St172 getters offer the possibility of being used as in-situ mini-pumps.

As it is well known, in spite of the high pumping speed of pump systems, the evacuation efficiency of the device is limited by conductance effects through the pumping tubulation. Thus the presence of a getter material such as St172, that becomes at least partially activated during the bake-out process, could develop an «internal» pumping action with a pumping speed much higher than the value of the conductance.

This results in a more efficient degassing process (since it is carried out under better vacuum conditions) or in a shorter duration of this process.

However if the getter is intended for this use some precautions may be necessary to avoid that the whole gettering capacity is consumed during the thermal processing. This can be achieved by a suitable choice of the quantity of getter material to be used.

Of course if, in spite of these precautions, the outgassing load during processing could eventually saturate or permanently damage the St172 getter, another suitable getter material which is not appreciably activated during processing (like St171) should be used.

ACTIVATION

The St172 material, like all other non-evaporable getter materials, must be activated to enable it to function as a getter. The activation must be carried out under vacuum at a temperature and for a time sufficient to remove, at least partially, from the surface of the getter material the thin protective layer formed at room temperature during air exposure.

The activation of St172 getter material can be obtained by heating in the temperature range 400 to 900°C for suitable time periods (1 to 10 min). In order to avoid damage to the material structure it is however advisable not to exceed 1000°C. Our measurements have been carried out using getters activated both at 450°C and 800°C for 10 minutes.

When only a limited activation time is available, shorter durations of the activation treatment are also possible, resulting in a reduction of sorption characteristics. For example activation at 450°C for 5 minutes would decrease to about 50% the relative sorption capacity for CO measured when the specific pumping speed is about $2 \text{ cc/sec} \cdot \text{cm}^2$. (This pumping speed is sufficient to cope with an outgassing rate as high as about $10^{-5} \text{ l torr/sec}$ when the pressure of the gases to be sorbed is about 10^{-5} torr).

A typical example of the influence of the activation temperatures on the sorption characteristics is shown by comparing the curves in fig. 1 (activation at 450-500°C) and fig. 2 (activation at 800-900°C).

ABSORPTION CHARACTERISTICS

The sorption temperature has little influence on the initial gettering rates while it introduces appreciable variations of the sorption capacity. For gases (CO , N_2) which form interstitial compounds, this is due to diffusion processes becoming important at higher temperatures. For hydrogen, which forms a solid solution, extremely large capacities are already available at low temperatures. However, at high temperatures, the increased hydrogen equilibrium pressure may reduce the practical sorption capacity for this gas.

In general St172 material has the good sorption capacity at high temperature typical of all non-evaporable getters. Its outstanding feature however is that it keeps an appreciable part of this capacity even when used at room temperature. Typical sorption characteristics of St172 material for CO at room temperature and 200°C are shown in fig. 2. (For comparison the sorption curves with the other porous getter material St171 in the same operating conditions are also shown).

Fig. 1

Fig. 2

ABSORPTION CURVES FOR LHI/4-7/200 TYPE GETTERS

(geometrical surface area: about 1 cm²;

weight of the getter material: 0.22 g for St171 version; 0.36 g for St172 version)

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St 172

**SAEB
Getters**

**Advanced Porous Getters
Types of St172 Standard Getters**

INDICATIVE TEMPERATURE-CURRENT CURVES FOR RESISTANCE HEATING St172 GETTERS

Other models may be made on request.

APPENDIX B: VYW-8028W SPECIFICATION

To : David Pirkle
From : Marv Anderson

Date: September 8, 1988

Subject: Performance Specifications of VYW-8028W Solenoid

The final specifications for the VYW-8028W Solenoid are attached. The operating and cold resistance have changed significantly since the last revision. We had to increase the outside diameter of the coils to provide a solid mounting method for the windings at the top of the unit when the inside diameter of the top end cap was increased to the present six inches. We decided to just increase the turns in the winding. In the heat of the effort I find that I haven't consulted anyone on this decision. The new winding has 149 turns compared to the original proposed winding of 135 turns. The following table shows the difference in operation between the two units. You should notice that the operating current required for a given field has reduced while the operating voltage has stayed constant:

	Original Proposal	Final Unit	Units
Absolute Maximum			
Current	55	55	Amps
Turns/Winding	135	149	Turns
Non-operating			
Resistance/Coil	.256/.293	0.299/0.342	Ohms
Maximum Operating			
Resistance/Coil			
at Nominal Current	0.367	0.430	Ohms
Nominal Proposed Current:			
Coils 1,4	51.47	46.63	Amps
Coils 2,3	47.82	43.32	Amps
Maximum Nominal Operating Voltage:			
Coils 1,4	19.35	19.40	Volts
Coils 2,3	17.55	17.71	Volts
Maximum Weight	126	126	Lbs

In summary, the final unit can generate the same field for less current at the same voltage or more field for the same current at a higher voltage. Since we met the weight and size requirements at the same voltage and power and at lower current, we've met your customers requirements but we should have notified everyone. The unit has also been tested at 50 amperes which is magnetically equivalent to operating the originally proposed unit at 55.2 amperes. The original flux plot in our presentation at Livermore was for the originally planned smaller inside diameter pole pieces at the ends which will give a higher field per ampere-turn of the magnet. The latest magnet does not have those diameters when we tested it and, since other pole piece inserts are to be added when you use it, it seemed more appropriate to operate it at the highest current at which it will most likely be operated. I hope this meets your approval.

Varian Associates, Inc.
Microwave Equipment Division
Santa Clara, California, USA

01060314, Rev 2
Model VYW-8250W
E. O. ---

September 9, 1988

Sam Cohen

Model VYW-8250W Electromagnet

Description: Liquid Cooled Electromagnet for use with the VYW-8250 Pierce-wiggler electron beam forming system. The electromagnet consists of four independent coils which provide the field shaping capability for the beam forming system when energized with the proper currents.

ABSOLUTE RATINGS : See Notes 1, 2

Parameter:	I	T(in)	Q	Delta P	P	R1(20)	R2(20)	R3(20)	R4(20)
Units	: Adc	: C	: gpm	: psid	: psig	: Ohms	: Ohms	: Ohms	: Ohms
Maximum	: 55	35		40	200	0.342	0.342	0.342	0.342
Minimum	:		1.6			0.299	0.299	0.299	0.299
Notes	: 11		8.9	9		3	3	3	3

OPERATING PARAMETERS: See Note 11

Parameter:	I1,4	I2,3	Rop1	Rop2	Rop3	Rop4
Units	: Adc	: Adc	: Ohms	: Ohms	: Ohms	: Ohms
Maximum	: 50.00	50.00	0.430	0.430	0.430	0.430
Minimum	:					
Notes	: 10	4	4	4	10	4

Dimensions : Per Outline Drawing No. 01060442

Mounting Position : Any

Coolant : Water (Or equivalent flow of other coolant, Note 8 and 9)

Finish : Electroless Nickel

Weight : 126 Lbs

QUALITY CONFORMANCE INSPECTION (PRODUCTION):

Test	Conditions	Symbol	Min	Max	Units	Notes
Hydrostatic Pressure	Outlet closed, 200 psig applied, 5 minutes (min)		No Leaks			7,8
Pressure Drop	Flow rate = 1.6 gpm water	Delta P		40	psid	9

		Symbol	Min	Max	Units	Notes
			-----	-----	-----	-----
Insulation Resistance	Test potential 500 Vdc Time = 30 Seconds		50		megohms	5
Non-operating. Q=1.6 gpm Water, 20 C		R1(20)	0.299	0.342	Ohms	3
Resistance, All		R2(20)	0.299	0.342	Ohms	3
Coils in Series		R3(20)	0.299	0.342	Ohms	3
		R4(20)	0.299	0.342	Ohms	3
Operating Resistance		Rop1		0.430	Ohms	4.11
Q = 1.6 gpm Water		Rop2		0.430	Ohms	4.11
I1, I4 = 50.00 Adc		Rop3		0.430	Ohms	4.11
I2, I3 = 50.00 Adc		Rop4		0.430	Ohms	4.11
Field Polarity I = 50 Adc				Aiding		6

Notes:

1. Abbreviations and symbols used in this specification are as follows:

- I = Operating current, Adc (Numbers indicate coil)
- P = Hydrostatic pressure, psig
- Delta P = Pressure drop, psid
- Q = Coolant flow rate, gpm
- R(20) = Non-operating resistance corrected to 20 C, ohms
(Numbers indicate coil)
- Rop = Operating resistance, ohms (Numbers indicate coil)
- Rt = Non-operating resistance, coils at
temperature T(in), ohms
- T(in) = Temperature of coolant at inlet of magnet, C
- T1 = Temperature at measurement point 1, C
- T2 = Temperature at measurement point 2, C

2. The maximum ratings are not to be exceeded under any service conditions. Operation beyond these ratings will shorten the service life and may lead to early failure of the magnet. Any change in operating conditions that makes the magnet operate at a lower temperature (e.g. lower current, higher flow rate, lower inlet temperature, more efficient coolant) will result in lower power consumption, longer service life and higher reliability.

3. This measurement is made with coolant flowing, but with no power applied to the coils. When the temperature has stabilized, the resistance of the coils and the coolant temperature are measured. The resistance at 20 C is obtained by correcting the readings with the following formula:

$$R(20) = R_t \times \frac{248.1}{[T(in) + 228.1]} \quad \text{Ohms}$$

The resistance of the unit can be extrapolated to any temperature, T2 if the resistance is known at temperature T1 by the formula:

$$R(T2) = R(T1) \times \frac{[T2 + 228.1]}{[T1 + 228.1]} \quad \text{Ohms}$$

4. This measurement is made with minimum coolant flowing at the maximum inlet temperature and the indicated currents applied to the respective coils. When the unit has stabilized, the voltage reading across the coils is divided by the current to determine the operating resistance. When operated in this mode the unit will not exceed the maximum resistance values given nor the maximum coolant pressure drop.

5. The magnet shell and cooling system constitute ground for insulation resistance measurements. The test voltage shall be brought evenly up to the maximum specified in the time given.

6. All magnetic fields are to be aiding when the coils are connected in series.

7. No sign of leakage allowed after five minutes at pressure P.

8. Minimizing coolant corrosion and freezing damage: Do not allow coolant to freeze in the magnet. Remove all coolant before shipping or storing or when coolant freezing is anticipated. Do not operate the unit with inlet temperature below the local ambient dew point so that condensation forms on the unit. It is recommended that the maximum coolant flow rate be limited to less than 3.0 gpm to prevent cavitation and resultant corrosion acceleration due to high coolant velocity. Small traces of high purity water left in a stored unit will cause accelerated corrosion in copper. Dry the unit thoroughly before storage, especially if high purity water was used in testing or operation.

9. Liquid coolants other than water can be used to cool the unit. Please contact Varian MED Magnet Engineering to determine the required flow rate and pressure drop required for any specific coolant desired other than water.

10. Consult the Pierce-wiggler electron forming system data to determine current requirements to form the beam properly.

11. Operating Parameters show how the unit will operate under one specific energizing current condition at the maximum inlet coolant temperature and minimum coolant flow rate. The unit is capable of operating continuously at 55 Adc in all coils under the minimum coolant flow and maximum inlet coolant temperature without damage. However, at 55 Adc, the operating resistances will be higher than shown under Operating Parameters due to the increased operating temperature.

TEST PERFORMANCE SHEET

MAGNET MODEL VYW-8028W

CUSTOMER: Varian MTD, D Pirkle

SERIAL No. 0101

PURCHASE ORDER: 19620-251

DATE: 9/7/88

This solenoid will provide the required magnetic field for the VUW-8250 Pierce-wiggler electron beam forming system. For typical or maximum operating points for focusing this device, see the device data.

SPECIFIED PARAMETER	Limits		Measured	Units
	Min.	Max.	Test Data	
1. Coolant leak test at 200 psi for 5 minutes	X	X	OK	OK
2. Pressure drop at 1.6 gpm.	X	40.0	17.0	psid
3. Insulation resistance measured at 500 Vdc All coils to frame and cooling system t=30 sec to go from 0 to 500 V	50.0	X	>5000	Megohm
4. Non-operating series resistance Corrected to 20C	Rnop1 0.299	0.342	0.332	Ohms20C
	Rnop2 0.299	0.342	0.333	Ohms20C
	Rnop3 0.299	0.342	0.331	Ohms20C
	Rnop4 0.299	0.342	0.328	Ohms20C
5. Heat Run: Inlet Temperature Outlet Temperature Flow rate 1.6 gpm Current = 50.0 Adc, All Coils	34.0	36.0	34.7	C
	X	X	42.6	C
	Rop1 X	0.430	0.414	Ohms35C
	Rop2 X	0.430	0.411	Ohms35C
	Rop3 X	0.430	0.407	Ohms35C
	Rop4 X	0.430	0.400	Ohms35C
6. Axial Magnetic Field measured and within tolerance.	X	X	Pass	Pass
7. Weight	X	126	117	Pounds

Tested by

MA

Q.A.

9/7/88

VYW-8028W Gyro-BWO Beamstick Magnet

Axial Field, Plain Magnet Shell Only

M. ANDERSON
S/N 0101
9/8/88

VYW8028W Magnetic Field Profile, S/N 0101, 50.0 Ade All Coils
 M Anderson, 9/7/88

2	Distance		
	Flux	From Gun	
Position	Density	Pole Piece	
Inches	Gauss	Inches	
-1.00	594	10.50	
-0.50	868	10.00	
0.00	1251	9.50	
0.50	1624	9.00	
1.00	2062	8.50	
1.50	2386	8.00	
2.00	2656	7.50	
2.50	2852	7.00	
3.00	2974	6.50	
3.50	3046	6.00	
4.00	3097	5.50	
4.50	3136	5.00	
5.00	3152	4.50	
5.50	3140	4.00	
6.00	3108	3.50	
6.50	3068	3.00	
7.00	3002	2.50	
7.50	2889	2.00	
8.00	2702	1.50	
8.50	2437	1.00	
9.00	2076	0.50	
9.50	1619	0.00	
10.00	1170	-0.50	
10.50	791	-1.00	
11.00	521	-1.50	

Z position is measured from the top
 of the top pole piece.

APPENDIX C: 921-2000 VACION POWER SUPPLY

July 1987

87-900-020-01

PRELIMINARY
INSTRUCTIONS FOR
APPENDAGE PUMP
POWER UNIT 921-2000
921-2010

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SAFETY SUMMARY

This instruction manual includes information required for a qualified operator to safely and reliably perform those functions for which the product was designed.

Should the product not operate properly, the operator should call upon maintenance personnel who are qualified to troubleshoot and repair.

On several pages of the manual you will find the wordings:

⚠ WARNING ⚠ CAUTION NOTE

which have the following meanings:

⚠ WARNING

WARNINGS ARE USED WHEN FAILURE TO OBSERVE INSTRUCTIONS
OR PRECAUTIONS COULD RESULT IN INJURY OR DEATH TO HUMANS.

⚠ CAUTION

CAUTIONS ARE USED WHEN FAILURE TO OBSERVE INSTRUCTIONS
COULD RESULT IN PERMANENT DAMAGE TO EQUIPMENT
(VARIAN SUPPLIED AND/OR OTHER ASSOCIATED EQUIPMENT).

NOTE

Information to aid you in obtaining the best performance
from your instrument.

INTRODUCTION

The 921-2000 power supplies are designed to operate the following
Appendage pumps:

913-0032	]	
913-0035	]	2 l/s pumps
913-5000	]	(H.V. cable 924-0125)
913-0038	]	Miniature pumps
913-0041	]	(H.V. cable 924-0124)

A. GENERAL FEATURES

- H.V. output (+ 3500 vdc open circuit)
- Safe maximum output current (2 mA short circuit current)
- 270° analog current read-out
- Line selection (100 + 120 & 220 + 240 Vac, 50/60 Hz)
- Battery operable (nominal 24 Vdc)
- Dual recorder output (0 + +100 mVdc, 0 + +10 Vdc)
- Recorder output display at front panel (% - scale)
- Dual independent set-points, adjustable over full range
- Led signal of set-point-threshold

C. FRONT PANEL DESCRIPTION

1. Five decades current log scale from 10 nA to 1 mA
2. 0 + 100 % recorder output scale
3. ON/OFF main switch
4. Set-point push button
5. Set-point threshold led
6. Trimmer set-point adjust

C. REAR PANEL DESCRIPTION

1. Line terminal board (100-120, 220-240 Vac)
2. Fuse F1 (0,4 A - T-type for 100-120 Vac operation)
(0,2 A - T-type for 220-240 Vac operation)
3. Fuse F2 (Battery fuse 1 A T-type)
4. High-voltage connector (+ 3500 Vdc)

5. Accessory terminal board

1. Positive terminal for 24 Vdc battery supply
2. Negative terminal for 24 Vdc battery supply
3. Ground terminal (battery operation requires direct connection of 3 to lab. ground)
4. Common terminal (low [negative] recorder connection)
5. 0 to + 10 Vdc recorder output
6. 0 to + 100 mVdc recorder output

NOTE

<p>The external recorder must have "floating input" (no reference to ground) and min. input impedance of 1 MΩ. Terminals 5 or 6 are the "high" (positive) terminal connectors. terminal 4 is the "low" (negative) terminal connection.</p>
--

7. FREE

- 8 & 9. N.O. contact terminals for set-point and relay
 (8-9 open, for current higher than set-point)
 (8-9 shorted, for current lower than set-point)

The contact is rated for 220 Vac / 5A

10. FREE

- 11 & 12. N.O. contact terminals for set-point 2 relay (logic as per set-point 1).

D. SPECIFICATION

INPUT

Line:

- Low range : 100 - 120 Vac $\pm 10\%$ / 0.4 A max.
- High range : 200 - 240 Vac $\pm 10\%$ / 0.2 A max.
- AC input frequency : 50 - 60 Hz $\pm 5\%$

Battery:

- Nominal 24 Vdc : 21 Vdc min., 32 Vdc max., 1A max.

OUTPUT

- High voltage (open circuit) : + 3500 Vdc
- Short circuit current : 2 mA $\pm 8\%$

PROTECTION

- Line : Fuse 1 : 0,4A - Time lag / 100 and 120 Vac
- : 0,2A - Time lag / 220 and 240 Vac
- Battery: Fuse 2 : 1 A - Time lag

AUXILIARY OUTPUTS

- Recorder output 0 + 10 Vdc : 0 to + 10 Vdc floating voltage,
proportional to pump current
0 Vdc = 10 nA, 10 Vdc = 1 mA
recorder min. impedance 1 M Ω
no reference to ground
- Recorder output 0 + 100 mVdc : 0 to + 100 mVdc floating voltage
proportional to pump current
0V = 10 nA, 100 mVdc = 1 mA
Recorder min. impedance 1 M Ω
No reference to ground
- Set-points : N.O. contact, rated 220 Vac,
5 A nominal
- Front panel meter : 0,01 to 1000 μ A
- Weight : 2 Kg. / 4 lbs
- Dimensions : 96 x 96 x 255 mm
3,75 x 3,75 x 10 inches
- Operating temperature : 0 + 50°C - 32 + 122°F

E. INSTALLATION AND OPERATION

After receipt of unit inspect it for any physical damage that may have occurred during shipment.

1. Connect the power cord leads to the line terminal acc. to given mains supply.

Note: F1 must be choosen:

- 0,4 A for 100 and 120 Vac
- 0,2 A for 220 and 240 Vac

F2 battery operation 24 Vdc:

- 1 A (use accessory terminal 1 and 2)

NOTE

The unit is shipped without main fuse 1. The appropriate fuses (acc. to line voltages) are in the nylon bag attached to the unit. This bag also contains mounting brackets for panel mounting.

2. Connect the pump and control unit by:

A. Cable 924-0125 for pumps:

913-0032

913-0035

913-5000

8. Cable 924-0124 for pumps:

913-0038

913-0041

3. Plug the main power cord to the mains-wall-terminal
4. Switch the unit on
5. Set the set-points by pressing the set-point button and adjusting the choosen value with trimmer potentiometer at the front panel.
Auxiliary contacts of set-points are accessible at the accessory panel at the rear, terminal 8 & 9 for set-point 1, 11 & 12 for set-point 2.

F. TROUBLESHOOTING

SYMPTOM	POSSIBLE CAUSE	CORRECTION PROCEDURE
1) With ON/OFF switch in ON position the meter indicates 10 nA current.	Fuse F1 (if the unit is supplied by a.c. line) or F2 (if the unit is supplied by battery), blown. Terminal 4 of the "Accessory" terminal board is connected to ground.	Replace the appropriate fuse. Check the ohmic resistance between terminals 3 (ground) and 4 (com.); it must be higher than 10 ohms.
2) With the unit connected to a pump at pressure higher than 10^{-8} Torr, the meter indication is lower than 10 nA.	Connection between the unit and the pump not properly made.	Switch-off the unit and check the connection.
3) With the unit properly connected to a pump at an unknown pressure, the meter indication is lower than 10 nA.	The pressure inside the pump is lower than 5×10^{-9} Torr	Switch-off the unit. Allow pressure to rise. After some minutes switch ON the unit and note current decrease.
4) Current reading is higher than expected.	Field emission current.	Hi-Pot the pump to 10 kV (1 mA) to remove sharp edges or "whiskers" which form on the pump electrodes and produce field emission current.

G. REPLACEMENT PARTS LIST

DESCRIPTION	REFERENCE	PART NUMBER 921-2000	PART NUMBER 921-2010
High voltage board assy! (complete)	PCB 2	03-645027	03-645027
Metering board assy (complete)	PCB 1	03-645310-01	03-645310-02
Meter assy (complete)	M 1	03-645306-01	03-645306-02
Connector H.V.(Fisher)		51-441200-01	51-441200-01
Switch	S W 1	71-159964-01	71-159964-01
Int. circuit 3403	U6 - U8	62-000119-01	62-000119-01
" " 741	U 9	62-000124-01	62-000124-01
" " 8048	U 5	62-000125-01	62-000125-01
" " CD 4011	U 7	62-602006-01	62-602006-01
" " 741	U 4	62-601982-01	62-601982-01
Transistor BC 207	Q2-Q5-Q6	62-000121-01	62-000121-01
Diode 10D6	1CR4-15-16-17-18	66-396950-01	66-396950-01
Diode 1N914	1CR5-6-7-8-9-10	66-397972-01	66-397972-01
LED yellow	LP 1	67-500008-01	-
LED green	LP 2	67-500009-01	-
Push button	SW2 - SW3	71-210100-01	-
Relay	A - B	72-110000-01	-

DESCRIPTION	REFERENCE	PART NUMBER 921-2000	PART NUMBER 921-2010
Relay	K	72-115990-01	72-115990-01
Trimmer 1 K Ω	R 17	37-580410-01	37-580410-01
" 2 K Ω	R11-12-52	37-580420-01	37-580420-01
" 10 K Ω	R36-R45	37-586510-01	-
" 20 K Ω	R 55	37-580520-01	37-580520-01
Cap.electr. 22 μ F 25V	C7 - C16	40-012222-01	40-012222-01
" " 47 μ F 25V	C 11	40-012247-01	40-012247-01
" " 100 μ F 25V	C13 - C14	40-012310-01	40-012310-01
" " poliest. 1 μ F	C9 - C12	40-142110-01	40-142110-01
" ceramic 10n F	C8 - C15	40-231210-01	40-231210-01
Fuse 5,2 x 20 T 0.4 A	F 1	67-150340-01	67-150340-01
Fuse 5,2 x 20 T 0.2 A	F 1	67-150320-01	67-150320-01
Fuse 5,2 x 20 T 1 A	F 2	67-150410-01	67-150410-01

APPENDIX A

Current / Pressure Diagram

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APPENDIX D: S/N 001 TEST PERFORMANCE SHEET

Serial No. 001

CATHODE TEMPERATURE

$T = 1050^{\circ}\text{C}$ at $V_H = 10.24$ Vac, $I_H = 3.25$ Vac

GETTER ACTIVATION

$I_{\text{Getter}} = 10.5 - 11.0$ Aac

$V_{\text{Getter}} \approx 7.5$ Vac for each getter

≈ 15 Vac for both getters in series

HI-POTTING

Cathode to Anode

VOLTAGE

46 kV

48 kV

LEAKAGE CURRENT

<70 μA

Arced outside over insulator;
needs to be hi-potted in oil

CATHODE ACTIVATION

$V_H = 9.5$ Vac $I_H = 3.0$ Aac

$V_{\text{cath}} = 300$ Vdc $I_{\text{cath}} = 2$ mA

$V_{\text{cath}} = 500$ Vdc $I_{\text{cath}} = 4$ mA

VACUUM

After pinch-off <0.1 μA
After valve installation 5-150 μA on 2 l/s pump

SOLENOID MAGNET: 66 Gauss/A Solenoid field cf Fig. 1

Field at the Cathode: cf Fig. 2,3,4

Gun Coil

1st. Coil

2nd. Coil

3rd. Coil

4th. Coil

12.2 Gauss/A

1.454 Gauss/A

.363 Gauss/A

.104 Gauss/A

.025 Gauss/A