Operation Readiness Clearance (ORC) of SpinQuest (E1039) Microwave generator and control system

WBS 000.00.00.00

Waqar Ahmed and Dustin Keller

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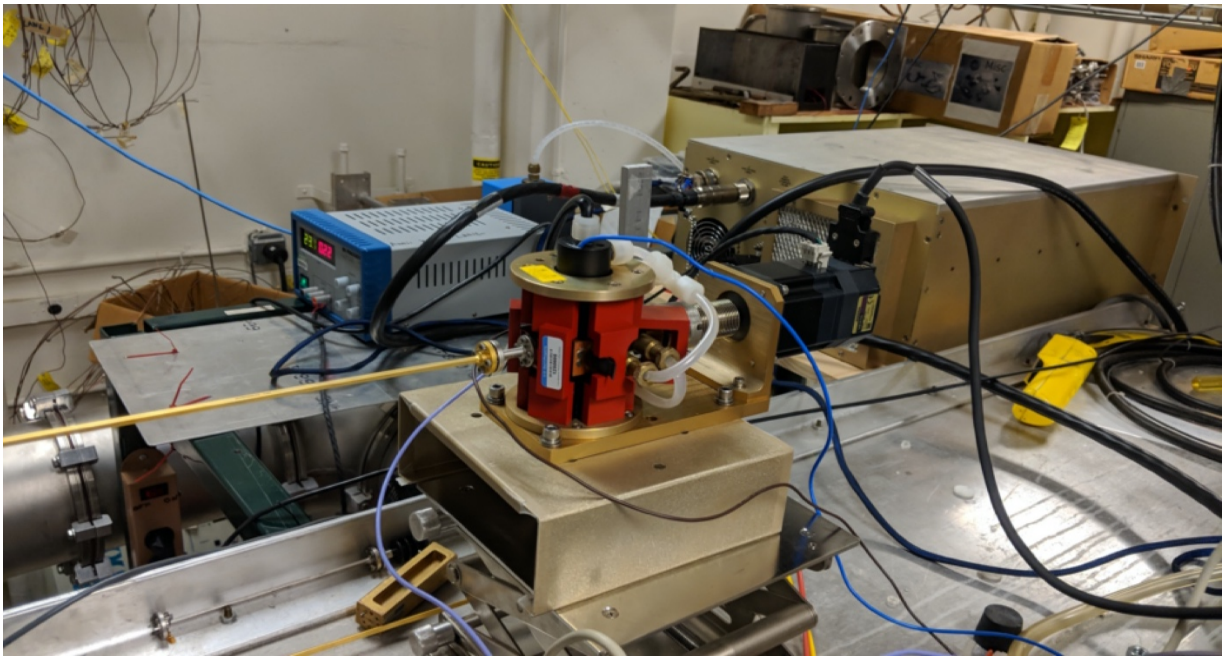
Extended Interaction Oscillator Specifications

1.0. INTRODUCTION:

The experiment will spectrometer in the NM4 enclosure with a modified beamline and will replace the current targets with a completely new transversely polarized system, jointly built by Los Alamos National Lab and the University of Virginia. This is a target with a transverse field configuration using the technique of dynamic nuclear polarization (DNP). In DNP, a microwave oscillator populates the desired polarization state through the hyperfine coupling between electrons and protons. It uses the fact that, while the electron spin relaxation time is short, the proton stays enhanced due to a long spin relaxation time.

The polarized target is one of the critical systems in the SpinQuest experiment at NM4. Many electronic instruments are required to polarize, maintain and measure the degree of polarization of the target. CPI Extended Interaction Oscillators (EIOs) VKT2438P6M high power motor tuned microwave oscillator may require high voltage power supply Varian 2838A2 adjustments to the cathode voltage and anode voltage to optimize the RF power output. Generally, the dominant effect of changes in cathode voltage will be to change the RF frequency. Changes to the anode voltage will predominantly change the EIO beam current and thus the RF power output.

The microwaves induce the spin-flip transitions and must be tuned very carefully to the frequency of the energy gap to maximize polarization. The microwaves are provided by the EIO tube, which allows the frequency of microwaves to be changed within limits by adjusting a bellows on the oscillation cavity. The waveguides carry the microwaves from the tube to a horn which shine on the target cups. The gold horn above the two target cups on the new target inserts. Two magnetic field strengths (5T and 2.5T) will be used and thus two nominal microwave frequencies will be used (140 and 70 GHz).



Microwave System by using EIO

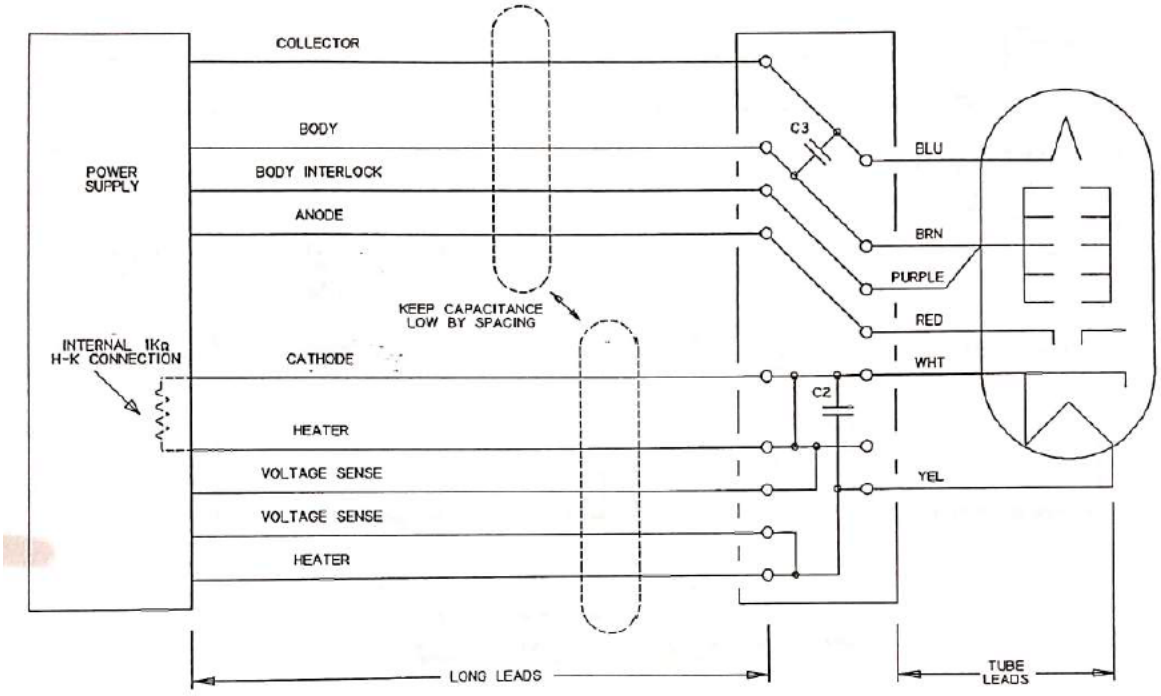
2.0. SCOPE:

This document details the performance specifications for the VKT2438P6M Extended Interaction Oscillator (EIOs) and different modules used for generating safe microwave power for the experiment. The optimal frequency changes as the target accumulate radiation damage from the beam. Therefore, the frequency is adjusted by adjusting the cavity size using a stepper motor through a remote-control system.

3.0. MICROWAVE SYSTEM MODULES AND CONTROL:

Sl No	ITEMS	Nos
1	a) EIO (VKT2438P6M) b) Varian High Voltage Power Supply Module (VPW 2838A2) c) EIP Microwave frequency counter d) Chiller Associated Cables and suitable pluggable HV connector to be provided from the common junction for connection between EIK Tube & Modulator and accessories e) Interlock system	**1** **1** **1** **1** **1** **1**

4.0. CONNECTION DIAGRAM up to 3M OF EIO AND POWER SUPPLY:



5.0. GENERAL TECHNICAL SPECIFICATION:

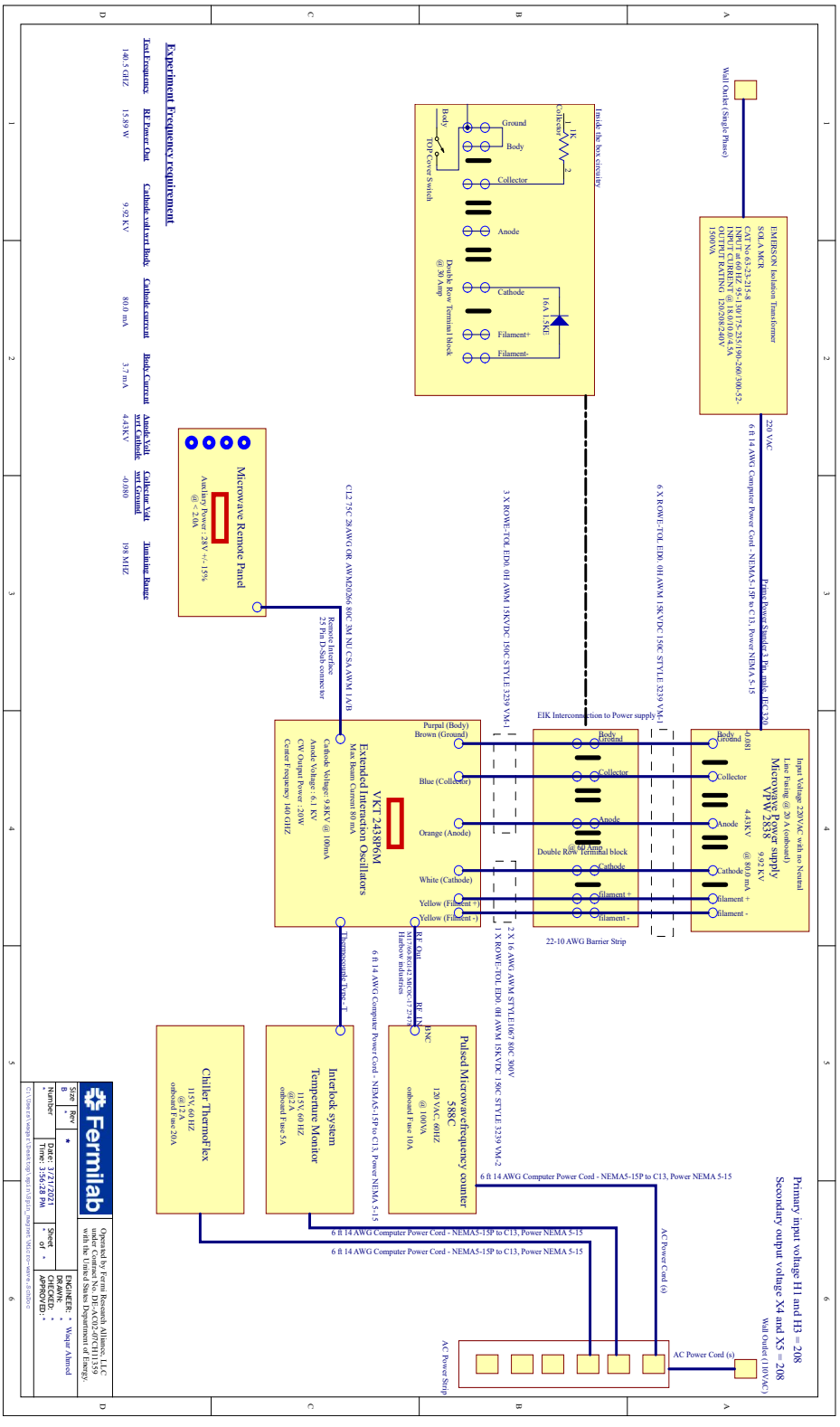
S. No	General Specifications
1.	Complete control and system parameter measurement over a remote interface
2	Less than 1.5 joules of energy are stored in high voltage circuits. This is significantly reducing the risk of damage to expensive components. The amount of stored energy is significantly less than the amount of energy that typical low voltage power supplies deliver under fault conditions.
3.	Fully encapsulated high voltage circuits are designed using the same rules employed in low voltage power supply designs.
4.	All hardware components should be Standard Industrial grade
5.	Output HV cable and connector should not be custom made, standard to be mentioned separately. The location of the HV connectors should be mentioned separately with dimensions.
6.	HV cable length to be finalized with SPINQUEST group during development as per system engineering requirement
7.	All the connectors, display, indicators, and manual knobs should be provided on the front panel of the unit
8.	All electrolytic capacitors are hermetically sealed or rated long-life products requiring minimal maintenance.
9.	Remote cathode voltage control for phase-locking RF output.

6.0. INITIALIZATION CHECKLIST

This is recommended that the following checklist be covered before applying any voltages:

Sl. No.	**Specification**
1	Connect the collector to the power supply.
2	Connect the body (normally ground) to the power supply.
3	Ensure the heater, cathode and anode leads arc adequately insulated; connect the leads to their respective power supplies.
4	Ensure coolant now is adequate.
5	Ensure, by the use of trips, adjustment stops, etc. that the absolute ratings will not be exceeded.
6	Connect the 0/P flange and the 1/P flange (where applicable) to suitable RF loads.
7	Ensure personnel will not be subject to exposure from the microwave fields.
8	Ensure personnel cannot come into contact with any high voltage.

7.0. Microwave Interconnection wiring diagram:



8.0. Isolation Transformer

Emerson power conditioner is used as input of Microwave system. Superior voltage regulation of ±1% sets the CVS series apart from other power conditioning technologies on the market. Extremely tight regulation is accomplished by SolaHD's farro resonant transformer technology. The CVS recreates a well-regulated sinusoidal waveform that is well isolated from input disturbances including:

- Impulses
- Brownouts
- Severe waveform distortion
- Swells
- Sags

VA	Catalog no	Voltage input	Voltage output
1500	63-23-215-8	95-130/175-235/190-260/300-520	120/208/240V

9.0. EIO VKT2438P6M

i. Introduction:

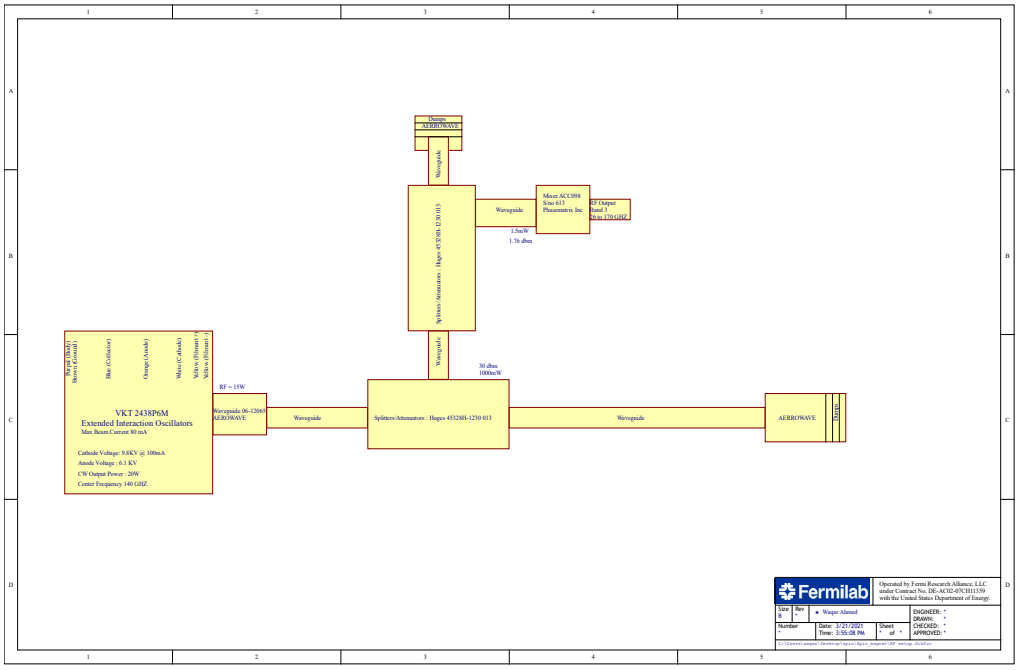
Communication and Power Industries Canada (CPI) has manufactured millimeter-wave Extended Interaction Klystron (EIK) vacuum tubes and they generate or amplify millimeter wave energy through interaction between a linear electron beam and resonant cavities similar to conventional klystrons.

ii. Scope:

This document details the performance specifications for the VKT2438P6M Extended Interaction Oscillator (EIOs). The VKT2438P6M is a 140.0 GHz CW Motor Tuned Extended Interaction Oscillator manufactured to CPI Canada commercial workmanship practices.

iii. Setup Description:

The microwaves for the dynamic nuclear polarization (DNP) are provided by the EIO tube, which allows the frequency of microwaves to be changed within limits by adjusting a bellows on the oscillation cavity. Waveguides carry the microwaves from the tube to a horn which shine on the target cups to polarize the NH3/ND3. In our tabletop setup, we do not have the horn in place for safety and instead, we have the microwave dump.



The microwave system consists of the CPI power supply, the EIO microwave tube, the frequency counter, and the wave guilds. About 15 W comes out of the tube directly but attenuates at no more than 5 db/m down to the target cell (or dump in this case). When rerouted to the mixer there is a 30 dbm split dropping the power by a factor of 1000 then a 10 dbm split dropping the power by another factor of 10 which makes it about **1.5 mW** right before the mixer (which has about a **10 mW** damage threshold). Once at the mixer the microwave is converted to RF electrical signals which beat against the oscillator in the EIP counter so you can read out the frequency by using the frequency counter.

iv. PERFORMANCE SPECIFICATION of EIO (VKT2438P6M)

Sl. No.	Specification	Range	Unit
1	Centre Frequency	140.0	GHz
2	Mechanical Tuning Range	1.0	GHz
3	Electronic Tuning Range	200	MHz typical
4	Power Output	< 20.0	W-min, W-Typical
5	Cathode Voltage	9.8	kV
6	Cathode current	100	mA
7	Anode Voltage	6.1	kV

v. OPTIONS TYPICAL ENVIRONMENT of EIO VKT 2438

Sl. No.	Specification	Range	Unit
1	Fixed Frequency, Trim tuned, manual tuning, Motorized tuning	Yes	
2	Electrical Tuner voltage	12	V
3	Electronic Tuner current	0.26	Amp
4	Temp range	0 to +60	^{o}C
5	Altitude	Up to 1500	m

10.0. SAFETY PROECUATION OF EIO

Equipment, in which the EIOs are used, should protect personnel. Besides, to protect the EIO, installation and operating precautions must be observed, and absolute ratings must not be exceeded

i. High Voltage:

Voltages required for the operation can be dangerous and potentially fatal to personnel. Equipment must be designed with protective devices such as physical shields and failsafe interlock circuits on access panels to prevent accidental contact with high voltage. Interlocks should be built into the system to remove or prevent the application of cathode and anode voltage if any of the absolute ratings of the EIO are exceeded. Coolant flow installed and interlocks on the coolant exhaust side of the EIO.

ii. Microwave Radiation:

Precautions should be taken to prevent exposure of personal to the microwave fields produced by the EIO. Refer to : American National Standard safe Levels of Microwave Radiation published by the I.E.E.E., 345 East 47th Street, New, York., 10017, entitled A.N.S.I. C95.1

iii. Heater Voltage:

The heater voltage must be supplied from an isolated transformer or DC power supply which has adequate insulation. One side of the heater power supply (the positive if a direct current power supply is used) must be connected to the heater/cathode lead(white)

11.0. VPW 2838 Power Supply

i. Introduction:

The VPW2838 Power supply uses design features not found in other designs. These features simplify the total RF design process such that only RF components are required to complete a total subsystem design. By using a remote interface complete control and system parameter are measured. Less than 1.5 joules of energy are stored in a high voltage circuit. This significantly reduces the risk of damage to expensive components. The amount of stored energy is significantly less than the amount of energy that typical low voltage power supplies deliver under fault conditions. The use of a tube personality interface removes the need to make an internal adjustment when changing RF amplifiers or oscillators

specifically EIOs, EIA, and TWTs. The power supply provides fully encapsulated high voltage circuit are designed using the same rules employed in low voltage power supply designs. All electrolytic capacitors are hermetic sealed or rated for greater than 60,000 hours of life. This ensures a long-life product. Remote cathode voltage control for phase-locking RF outputs.

ii. ELECTRICAL SPECIFICATION of Input Power

Sl. No.	Description	Specification
1	Voltage ± 5% (Vac)	190 to 265, 1 phase with no Neutral
2	Apparent line power (VA) max	1650
3	Frequency (Hz)	47 to 63
4	Fusing (Breaker) (A)	10

iii. Output

Collector-to-Cathode:

The collector voltage w.r.t cathode shall be selected as per the EIK test report

Sl. No.	Description	Specification
1	Collector voltage w.r.t body	-10 to -60 Volts
2	Collector current	130 ma max
3	Power	< 1,000 watts
4	Collector regulation	+/- 2%
5	Collector ripple < 10 kHz > 10 kHz	< 20 Volt p-p typical < 2.0 Volt p-p typical
6	Stored energy	< .7 joule (.4 typical)
7	Peal short circuit current	< 30 amps (< .5 micro sec)

iv. Cathode-to-Body:

The cathode power supply provides the cathode to body voltage where the body is at ground potential

Sl. No.	Description	Specification
1	Voltage Range	-4.5 kV to -11 kV DC
2	Current	0 to 10 mA dc (max)
3	Trip Point	10 mA peak/average
4	Pulse width	200nSec to 17μSec **(excluding settling time)**
5	Peak short circuit current	< 60 A (< .6 micro sec)
6	Rise time	< .5 sec 98% final value
7	Settling time	20 nSec (max)
8	Energy Storage	The Energy Stored in the cathode-to-body power supply shall be less than 1.5 Joules at maximum voltage
9	*Ripple 47-130Hz.* *131-5kHz* *<5Khz*	< 5.0 V p-p typical < .2 V p-p typical < .3 V p-p typical
10	*Cathode current*	< 130 ma max

v. Anode Voltage:

The anode voltage is referred to as Cathode and turns on simultaneous with the Cathode/Body power supply

Sl. No.	Description	Specification
1	Voltage	2Kv to 6Kv min
2	Load current	< .20 to -1.0 ma
4	Rise time	< .5 sec 98% final value
6	Ripple voltage < 20 kHz > 20KHz	< .20 Volt p-p typical < .5 Volt p-p final value

vi. Filament Voltage:

The heater power supply provides heater to heater/cathode voltage. The voltage or current regulation is available, and voltage is referred to as cathode

Sl. No.	Description	Specification
1	Voltage	-3.7 to -7.4 volts
2	Steady-state Current	.5 to 1.5 amp dc
3	Surge Current	< 3.5 A (max)
4	Regulation	$\pm$ 2.0 % (max)
5	Filament Delay	125 $\pm$ 15 Sec (Filament Warm up)
6	Ripple voltage < 20 kHz > 20KHz	< .25 Volt p-p < .10 Volt p-p

vii. Protection Circuit

Interlocks should be built into the system to remove or prevent the application of cathode and anode voltage if any of the absolute ratings of the EIO are exceeded. Install coolant flow interlocks on the coolant exhaust side of the EIO.

Sl. No.	Description	Specification
1	**EIK Arc Protection**	The cathode-to-body power supply and associated output capacitance preferably shall have a series large current limiting resistance designed to limit the stored energy supplied to the EIK, in the event of a high voltage arc.
		Since the collector-to-Cathode power supply is a reference to the cathode, a spark gap shall limit collector-to-body voltage
		Focus electrode-to-Cathode breakdown protection to be provided by a diode to prevent the focus electrode from becoming more than +30V with respect to the cathode

viii. Interlocks & LED Display

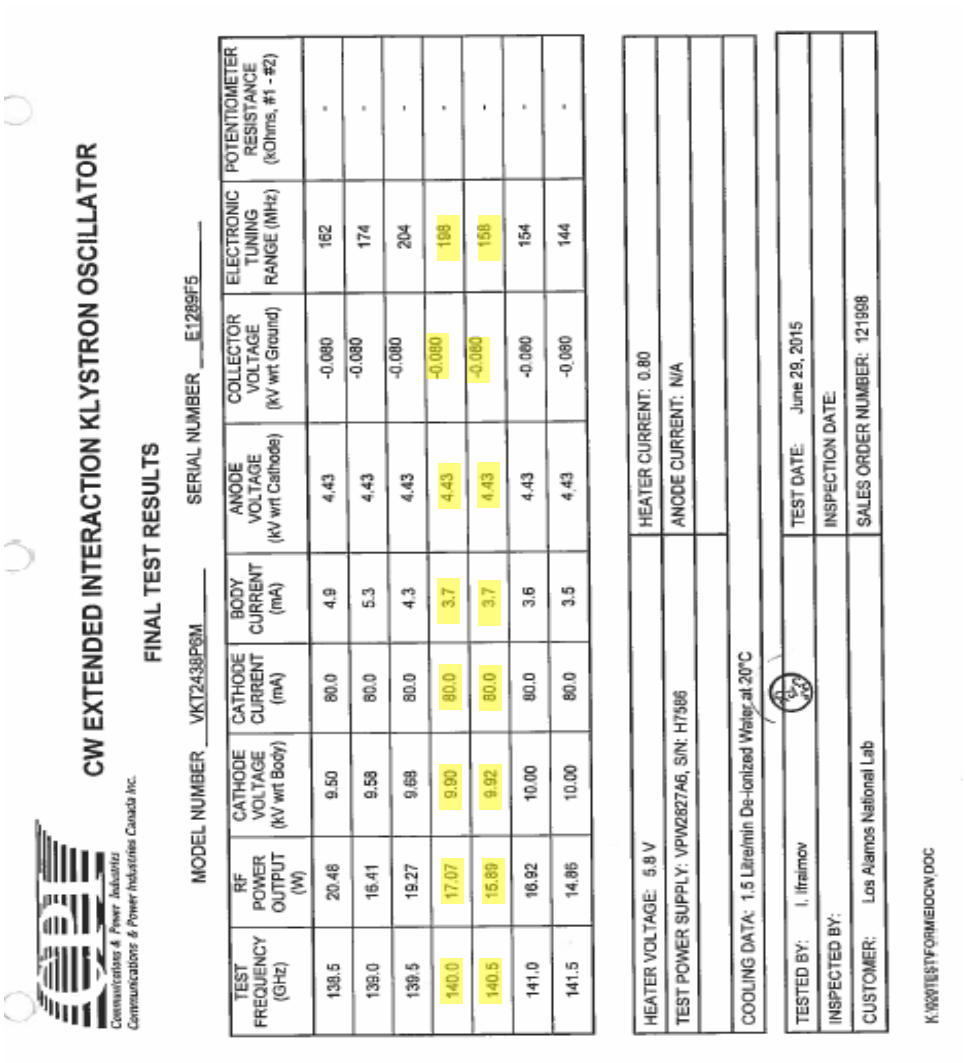
Sl. No.	Interlocks
1	Over Temperature
2	External Interlock
3	Excess Duty cycle
4	Helix Overcurrent
5	Cathode Overcurrent
8.	Hardware bypass option to be provided
9.	Interlock activated actions to be finalized with the SPINQUEST group during the development

ix. Indicators and monitoring ports

Following are the status indicators and monitoring ports (as applicable) that shall be available in the unit:

Sl. No.	Parameter
1	Filament Delay
2	Transmitter Power Valid
3	Transmitter Over Temp.
4	P/S Sync Fault
5	Modulator Fault
6	P/S Temp. Monitor
7	Cathode Voltage
8	Collector Current
9	Body Current

x. Final test result datasheet:



CW EXTENDED INTERACTION KLYSTRON OSCILLATOR

Communications & Power Industries

FINAL TEST RESULTS

MODEL NUMBER VKT2438P6M SERIAL NUMBER E1289F5

TEST FREQUENCY (GHz)	RF POWER OUTPUT (W)	CATHODE VOLTAGE (kV wrt Body)	CATHODE CURRENT (mA)	BODY CURRENT (mA)	ANODE VOLTAGE (kV wrt Cathode)	COLLECTOR VOLTAGE (kV wrt Ground)	ELECTRONIC TUNING RANGE (MHz)	POTENTIOMETER RESISTANCE (kOhms, #1 - #2)
138.5	20.48	9.50	80.0	4.9	4.43	-0.080	162	-
139.0	16.41	9.58	80.0	5.3	4.43	-0.080	174	-
139.5	19.27	9.68	80.0	4.3	4.43	-0.080	204	-
140.0	17.07	9.90	80.0	3.7	4.43	-0.080	198	-
140.5	15.89	9.92	80.0	3.7	4.43	-0.080	156	-
141.0	16.92	10.00	80.0	3.6	4.43	-0.080	154	-
141.5	14.86	10.00	80.0	3.5	4.43	-0.080	144	-

HEATER VOLTAGE: 5.8 V

TEST POWER SUPPLY: VPW2827A6, S/N: H7586

COOLING DATA: 1.5 Litre/min De-ionized Water at 20°C

HEATER CURRENT: 0.80

ANODE CURRENT: N/A

TESTED BY: I. Ifraimov

INSPECTED BY:

CUSTOMER: Los Alamos National Lab

TEST DATE: June 29, 2015

INSPECTION DATE:

SALES ORDER NUMBER: 121998

K:\9001\TEST\FORM\EIOCW.DOC

xi. SpinQuest operating voltage and frequency

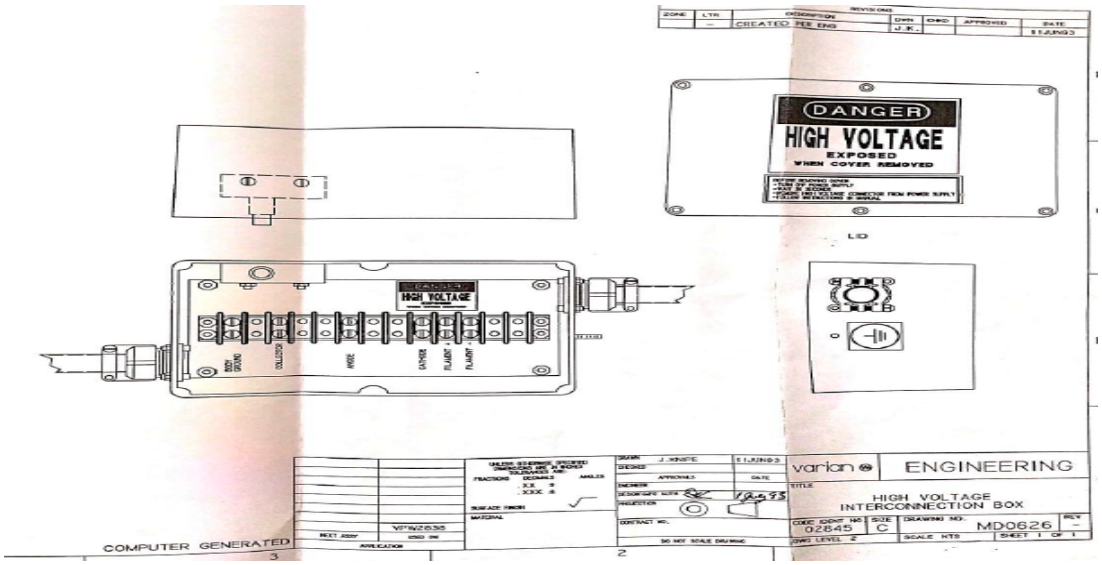
The SpinQuest operating frequency is 140 to 140.5 and set the voltage once according to the requirement from the back of the EIK power supply. No voltage options are available to change the voltage remotely.

xii. Interconnection Box

A high voltage interconnection box has been provided which enables a convenient and safe connection between the power supply and the EIO. The electrical connection on the EIO is as follows.

i. Cathode
ii. Filament+
iii. Filament-
iv. Collector
v. Anode
vi. Ground/Body

The interconnection box under the lid closes with a click if the box is open power supply shut off automatically.



Interconnection Box

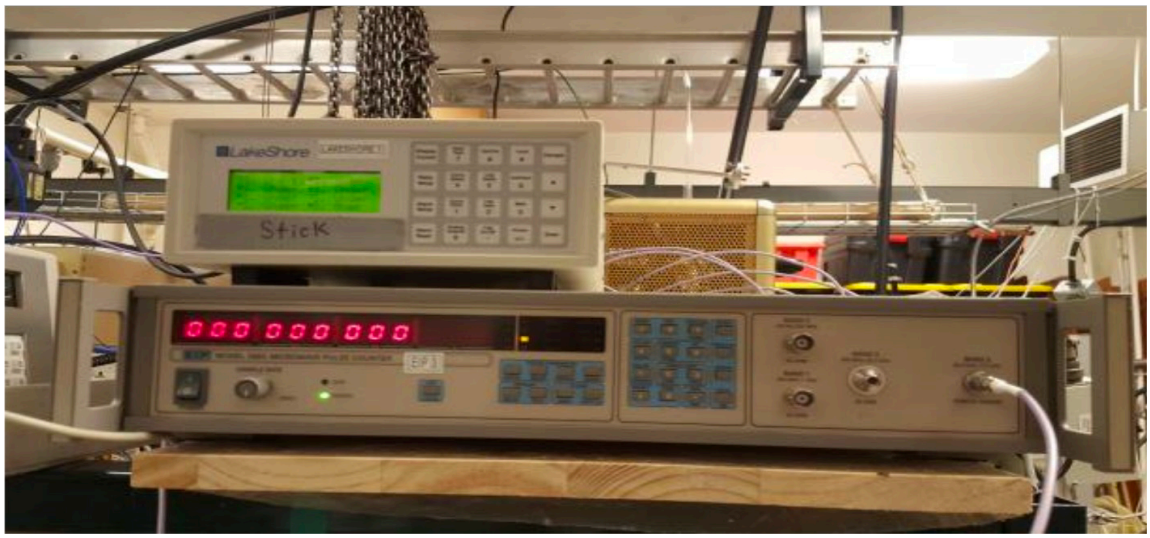
12.0. EIP frequency Counter

i. Description

The Microwave Frequency Counters Phase 588C are designed and tested according to international safety requirements and based on a microprocessor, multifunction instruments used for both CW and pulsed microwave measurements. They can automatically measure the frequency of repetitive pulse signals as narrow as 50 ns. Both models can also automatically measure pulse widths from 50 ns to 1 second and pulse periods from 250 ns to 1 second, to a 10 ns resolution. Additionally, with an optional built-in delaying pulse generator, the 588C can profile pulsed or chirped signals with measurement windows as narrow as 15 ns. No manual switching is required to measure CW or pulsed signals.

The frequency range of the counter is 100 Hz to 20 GHz. The frequency range of the 588C is 100 Hz to 26.5 GHz, and is extendible, by the option, up to 170 GHz. Band 0, 100 Hz to 250 MHz, is for CW measurements only.

The microwave frequency is read out via EIP 588C. In addition to being read out the frequency, position space is so mapped to allow for frequency seeking. The relationship is mostly linear, very much so locally map used to extrapolate using nearest neighbors and return calculated frequency.



The Phase Matrix 585C and 588C Pulsed Microwave Frequency Counters can automatically measure the frequency of CW and repetitive pulse signals having pulse widths as narrow as 50 ns. To measure the frequency of a CW signal, apply the signal to the input connector that corresponds to the frequency being measured and select the appropriate band. The counter then automatically finds the signal, measures it, and displays the measured frequency.

ii. Safety of the instrument:

Before the Microwave counter is switched on, its protective earth terminals must be connected to the AC power cord's protective conductor. The main plug must only be inserted in a socket/outlet that has a protective earth contact. The protective action must not be negated by using an extension cord (power cable) or adapter that does not he a protective earth (grounding) conductor.

iii. Instrument Default setting:

Parameter Default Value	**Parameter Default Value**
Band 2 (microwave band)	Band 2 (microwave band)
SSubband1	Subband 1
Resolution 3 (1 kHz)	Resolution 3 (1 kHz)
Special Function 00 (all cleared)	Special Function 00 (all cleared)
Average 01	Average 01
Frequency Multiplier 01	Frequency Multiplier 01
Frequency Offset 0 kHz	Frequency Offset 0 kHz
Minimum PRF 2 kHz	Minimum PRF 2 kHz
Frequency Limit Low 900 MHz	Frequency Limit Low 900 MHz
Frequency Limit High 20.5 GHz (Model 585C)	Frequency Limit High 20.5 GHz (Model 585C)
26.7 GHz (Model 588C)	26.7 GHz (Model 588C)

Center Frequency 0 kHz (not active)	Center Frequency 0 kHz (not active)
ΔF 50 MHz	ΔF 50 MHz
Frequency Display On	Frequency Display On
Pulse Period Measurements Off	Pulse Period Measurements Off
Pulse Generator (Optional)	
Width 1 μs	Width 1 μs
Delay 50 ns	Delay 50 ns
Period 10 μs	Period 10 μs

13.0. Cooling System

NESLAB's constant temperature refrigerated RTE Series feature three controller choices to meet our specific needs: analog, digital, and microprocessor. All are designed for precise control and convenient operation. The analog controller gives you full control over temperature parameters at an economical price. The digital controller features remote sensing capabilities and an RS-232 connection which provides direct computer communication. The microprocessor controller has the features of the digital controller and adds multistep programming, adjustable high and low-temperature safeties, and the ability to remove the controller for remote operation.

Chiller has a strong circulating pump that p provides twice the pump pressure as any other brand available. The pump motor has a large 5/16"(.8cm) one-piece shaft which is part of the pump rotor. Pump fittings are 1/4"(.64cm) MPT for convenience, and the angled design allows bath fluid to drain back into the reservoir before making tubing changes. The RTE-111, 211, and 221 provide generous CFC-free cooling for your demanding applications. You can choose analog, digital, or microprocessor control functions. These baths are designed to be compact and are ideal for your benchtop cooling needs. NESLAB Refrigerated Bath/Circulators are specially designed to outperform any other brand on the market. Compare cooling capacity in Watts or BTU/hr and you'll see why owning a NESLAB Refrigerated Bath/Circulator is clearly a better value.

i. Electrical Configuration:

Units equipped with the Global Voltage option have a voltage configuration panel located behind the refrigeration access panel on the rear of the unit. Use a 1/4" socket to remove the four screws securing the access panel to the unit. The configuration panel has two 3-position toggle switches, one for voltage and one for frequency. All units are shipped with the toggle switch in the center SHIP position. Place each switch to the settings that match the voltage/frequency supplied to the unit.

NESLAB	Voltage Frequency	Phase Branch Circuit	Line Cord	Requirements Plug
120 VAC	60 Hz	1Φ	12A	5-20P

14.0. Microwave System Power calculation:

S.no	Load Description	QTY	Voltage (VAC)	Full Load (Amps)	Total Power (kVA)
1.	Microwave Generator	1	208	15.86	3.489
2.	Water Chiller Microwave	1	120	12	1.44
3.	Interlock System	1	120	2.0	0.24
4.	Pulsed Frequency counter	1	120	3.0	0.36
	Total				**5.529**

15.0. Mechanical Specification of Waveguide:

S.no	Items	Specification
1	Waveguide	RG-138/U (WR8)
2	Waveguide Flange	Mates with UG387/U
3	Waveguide Pressurization	N/R
4	Input Power connectors	Flying Leads
5	Lead Length	45.0 cm min Swagelok type 6.35mm (1/4") tubing
6	Coolant hose connectors	Swagelok type 6.35mm (1/4") tubing
7	Tuning methods	
8	Number of complete tuning cycles	1000 min