OPERATIONS AND MAINTENANCE MANUAL

PLASMOD
Plasma System

NOTE: 6th major revision

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INTRODUCTION

This manual is broken down into sections dealing with all issues related to the Plasmod Plasma Treatment System.

This includes detailed installation instructions, specifications, and a full description of the equipment and all controls and indicators on the equipment components.

A safety hazards and precautions section points out any risks involved with equipment operation along with recommendations for safely operating and maintaining the system. The safety features included with the system are also outlined.

A section on theory of operation explains the principals behind plasma generation and the variables that are under operator control during process development and optimization. The goal is to give the beginning plasma process engineer a starting point for developing plasma treatments for various applications using the Plasmod equipment. The user should contact March Instruments if more detailed process development assistance is required for a specific application.

Another section gives the step by step details for operation of the equipment.

The service information section contains the information on warranties, trouble shooting, equipment repair, and parts replacement.

The appendix lists a detailed explanation of the effect of changing the variables in the plasma process and a characterization of some aspects of the system.

A glossary defines the terms used in the manual.

Textural conventions used in the manual are as follows:
In the Installation Instructions section, parts that the installer needs to attach to the main unit are listed in all capital letters. In operating procedures, call-outs for buttons the operator is instructed to actuate are listed in all capital letters. Section headings are in bold print and underlined.

Nomenclature for data entry in this manual and on the system itself uses Torr in reference to pressure, watts (w) for power, and seconds (secs) or minutes (mins) for time.

This is the sixth revision of the Plasmod manual. This manual can be ordered under March Instruments part number 021-1001.

EQUIPMENT OPTIONS

This is a list of all non-standard system accessories. Equipment can be upgraded to include any of these options. For additional information, contact March Instruments.

AUTO TUNING

An auto tuning system may be installed for the matching network. The auto tuning option adds circuitry which continually monitors the forward-to-reverse power ratio during processing and positions the air capacitors for optimum power transfer to the chamber. This option makes the system much more user friendly.

PUMP OIL FILTRATION UNIT

Pump oil gets dirty during the course of normal operation. Certain plasma processes will cause the oil to accumulate contaminants at an accelerated rate. The pump oil filtration unit is a device that attaches to the vacuum pump and keeps the pump oil clean. This cuts down on pump maintenance and increases the life of the pump.

PUMP OIL MIST ELIMINATOR

Collects and condenses the oil mist generated during pump operation. This leads to lower pump oil consumption and a cleaner operation. If system will run fluorine based process gas, a special mist eliminator is required.

GAS CONTROL MODULES

GCM-250 - Consists of three flowrators, a pressure gauge with low set point capability, and automatic sequencing with a digital RF timer. Used to monitor and automate the Plasmod.

GCM-200 - Consists of two flowrators, a pressure gauge with low set point capability, and automatic sequencing with a digital RF timer. Used to monitor and automate the Plasmod.

GCM-100 - Consists of three flowrators for accurate gas mixing and a pressure gauge. Operation is manual.

GCM-50 - Consists of one gas flowrator and a pressure gauge. Operation of this unit is completely manual.

250 WATT GENERATOR

The standard generator supplied with the system is 150 watts. For more power, an optional 250 watt power supply may be purchased.

END POINT DETECTOR

A light sensitive detector and chart recorder can be added to the Plasmod to monitor the end point of an oxygen cleaning or etching process. The detector is calibrated for the blue light produced by CO and CO2 plasmas. These two gases are by-products of the oxygen plasma's reaction with organic material. When all organics have been oxidized, the CO and CO2 will be flushed from the chamber and the emission will end. The detector signal is monitored by a strip chart recorder.

SIX INCH CHAMBER

The standard chamber diameter is 4 inches. For larger chamber volume, a 6 inch diameter chamber can be purchased.

SAFETY

This section covers the safety issues associated with the Plasmod. It describes the system safety features. Any inherent equipment hazards are outlined. Details on necessary precautions for safe operation are provided.

Alert boxes containing the words” NOTE”, “CAUTION”, and “WARNING” are used in various advisories in this manual. “CAUTION” implies that the action could possibly cause damage to equipment or injury to personnel if the proper procedures are not followed. Use of the word “WARNING” implies that the action places the operator in a situation that has a possibility of injury or death if the proper procedures are not followed. “NOTE” alert boxes are advisories that point out important information that is not obvious to the reader but will not lead to any hazardous situations or immediate equipment damage if not followed.

SAFETY FEATURES

The following is a description of the safety features designed into the system. Schematics are in the back of the manual.

SAFETY INTERLOCKS

There are five RF power interlocks engineered into the instrument to prevent injury to operating personnel. These will shut off RF power if they are activated. These interlocks are:

Access Door Interlocks - Two interlocks located at the left and right bottom of the Plasmod chamber access door. The RF power cannot be activated if the door is open. The RF power will shut off if the door is opened during operation.

Enclosure Interlocks - Two interlocks located along right side of chassis, front and rear. If either of the screws holding the right side of the exterior chassis panel in place are removed, the RF power will shut down and cannot be reactivated until either the screw is replaced or the interlock is defeated.

Vacuum Interlock - The vacuum switch must be activated to activate RF.

WARNINGS AND PRECAUTIONS

When used properly, your Plasmod plasma system is very safe. The purpose of this advisory is simply to point out possible hazards resulting from misuse of the equipment and to suggest ways of operating the equipment as safely as possible.

ELECTRICAL

As with all electrical equipment, caution is warranted whenever external panels are removed and/or electrical wiring is exposed. Only qualified technicians should perform maintenance, repair or installation on the equipment.

RADIO FREQUENCY (RF) EXPOSURE

A hazard from RF exposure exists if the system is operated without the door closed and/or the exterior panel in place. This would require defeating safety interlocks and is not recommended. This system runs at an RF frequency of 13.56 MHz and the standard RF generator runs at a maximum power of 150 watts.

CHAMBER TEMPERATURE

The plasma chamber can become quite hot during some processes. Exercise caution to prevent burns.

CHEMICAL HAZARD

The fluorinated pump oil (Krytox) is a skin and eye irritant. Gloves and eye protection should be used when changing or adding pump oil.

The Material Safety Data Sheet for Krytox is included for reference at the back of the manual.

PROCESS GASES

Certain process gases selected for use with this equipment may be hazardous. Some may require special precautions. These precautions vary depending on the gas. Consult with your safety officer to ensure proper precautionary steps are taken before bringing any new gas into your facility. Take care to insure that gas lines containing toxic or flammable gases do not leak.

Gas line integrity can be confirmed simply by opening the valve on the gas cylinder then quickly closing it again. If the pressure reading on the regulator drops within one minute, there is a substantial leak that could be dangerous.

One of the gases most frequently used in the Plasmod is oxygen. If the system uses oxygen, no smoking signs should be posted near the instrument and the no smoking ban observed.

UNPACKING

The Plasmod Plasma System is completely tested and inspected at the factory before shipping. Inspect the carton before unpacking. If there is any reason to suspect damage to the carton or it's contents, make note of the damage and report it to the shipping company immediately.

Using the included packing list, check to ensure that all listed components have arrived at your facility. Unpack the shipping cartons carefully and inspect the main plasma unit and all other system components for any damaged or missing items.

If any component is damaged or missing, notify the shipper and notify the March Instruments Customer Service Department by TELEPHONE (925) 827-1240 or by FAX (925) 827-1189 immediately. Claims based on late notification of shipping damage will be denied.

Keep all shipping containers and materials in case it should be necessary to return any item to March.

Place the system components on the selected work surfaces. Remove all packing materials including any that might be present in the chamber of the system.

LONG TERM STORAGE

If the plasma system and vacuum pump are to be placed in long term storage, take the following precautions in order to keep the equipment in good working condition.

All system components should be placed in protective packaging. A desiccant should be placed in the packaging to minimize moisture exposure. Storage should be in a room with humidity less than eighty percent.

Before packaging and storing the vacuum pump, fill the pump reservoir with oil to the proper level and run the pump for five minutes to lubricate the seals. During the time the pump is stored, you will also need to run the pump for five minutes every three months in order to keep the seals lubricated.

INSTALLATION

The following section outlines the requirements for system installation, step by step instructions for assembly, and initial startup procedure. The installer should refer to Safety Warnings and Precautions and Unpacking sections on pages 7 and 8 before beginning installation.

FACILITIES REQUIREMENTS:

The specifications and requirements for the system and applicable options are listed in the following table. All power cords are supplied by March Instruments.

ETCHER:

Power Supply:.....................	Single Phase 110VAC, 15 amp or 220VAC, 7 amp. Voltage is +/-10%. 50-60 Hz. 18 AWG, 3 wire.
Process Gases:.....................	Regulated to 10-15 PSIG. Connections made by either .25” O.D. Stainless Steel or Teflon tubing (Supplied by purchaser).
External Gas Fittings:..........	Swagelok compression fittings, .25” O.D.
Dimensions, Door Closed:...	12” W x 11.1”H x 17”L.

VACUUM PUMP:

Capacity:............................	1005C/3.2 CFM, 2015CP/11CFM (3.2 CFM minimum recommended).
Power Supply:.....................	1005C - Single Phase 110VAC, 7 amps or 220VAC, 3.5 amps. Voltage is +/-10%. 50-60 Hz. 16 AWG, 3 wire. 2015CP - Single Phase 110VAC or 220VAC +/-10% @ 50-60 Hz and 15 Amps. 14 AWG, 3 wire.
Lubricant:...........................	Charged with either Perfluorinated Krytox or Fomblin oil.
Exhaust:.............................	NW-25 connection(1” I.D. wire reinforced PVC exhaust tubing/piping supplied by purchaser).
Dimensions:.......................	1005C - 18.5”L x 10”H x 5.5”W. 2033CP - 30”L x 14”H x 8”W.

Optional Equipment

PUMP OIL FILTRATION UNIT:

Power Supply:..................... Single Phase 110VAC or 220VAC +/-10%. 50-60 Hz @ 8 Amps. 14 AWG, 3 wire.
Dimensions:....................... 13"W x 14.5"H x 17.5"L.

CONTACT ANGLE MEASURING SYSTEM:

Power Supply:..................... Single Phase 110VAC or 220VAC +/-10%. 50-60 Hz @ 2 Amps. 3 wire, 14 AWG.*
Dimensions:....................... 11"W x 16"H x 22.5"L.

NOTE: ALL CONNECTIONS FOR PROCESS GAS BETWEEN GAS BOTTLES AND PLASMOD MUST BE MADE USING CORROSION RESISTANT MATERIALS SUCH AS TEFLON OR STAINLESS STEEL. OTHER MATERIALS CAN CORRODE GENERATING PARTICULATE MATTER WHICH WILL CLOG GAS SHUTOFF VALVES.

* 220VAC with external transformer supplied with system.

SYSTEM ASSEMBLY

The assembly required when setting up a Plasmod consists of installing the outer chamber into the electrodes and making the necessary connections to gas, vacuum, and electrical power. If the unit is being installed with a Gas Control Module, see the instructions included with that module for information on connecting it to a Plasmod. The Plasmod should be installed in a location where the intake for the cooling fan is not obstructed.

1.) With the instrument resting on a convenient work surface, remove the four screws along at the bottom of the top cover. Remove the top cover only.

2.) Open the door and remove the spring-loaded PINCH CLAMP from the VACUUM/EXHAUST MANIFOLD.

3.) Slightly loosen the four nylon RETAINING SCREWS from the CHAMBER SUPPORT.

CAUTION: NEVER USE METALLIC SCREWS IN PLACE OF NYLON SCREWS. THESE WILL SHORT CIRCUIT THE CHAMBER ELECTRODES.

4.) Remove the OUTER CHAMBER from its shipping container. Make sure that there are no cracks in the chamber and that there is no packing material in the chamber.

5.) Gently slide the OUTER CHAMBER into the ELECTRODES. Please note that the vacuum/exhaust manifold has to be pushed down in order to slip the ball shaped end of the outer chamber vacuum fitting into the manifold.

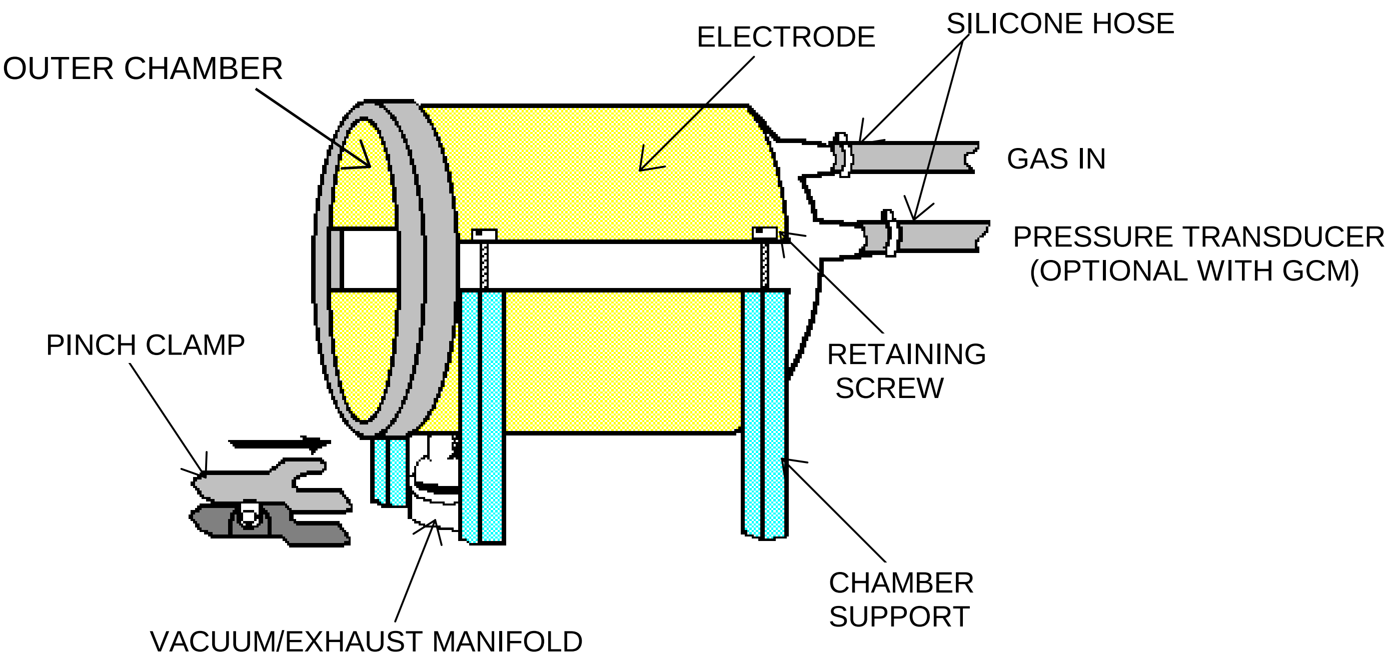
6.) When the ball joint is in place with the "O" ring seal inside the manifold, compress the PINCH CLAMP and slide it over the vacuum connection as shown.

7.) Connect the 1" vacuum hose to the vacuum port at the rear of the unit, item 15 of figure 3-2, page 19. The hose is supplied with two clamps. Make sure that both clamps are securely fastened.

8.) Re-tighten the nylon RETAINING SCREWS. Do not over tighten, since this can damage the threads.

9.) For the standard 4” chamber:
On the inner chamber section, make sure that the sealing "O" ring is not twisted and will seat against the inner lip of the chamber section.

For the optional 6” chamber:
Install 5" silicone door gasket onto chamber so that it overlaps the top and bottom electrodes. Stretch the entire gasket evenly around the chamber electrodes, then pull the lip portion of the gasket towards you so that the gasket lip falls uniformly around the forward portion of the chamber. This operation is best performed by two people.



10.) If you are not using a Gas Control Module, connect the regulated gas supply hose to the 1/4 inch fitting labeled GAS IN (item 10 of Figure 3-2) on the rear of the system. Secure the gas line connection to the rear of the chamber with the 1/4 inch CLIP LOCK.

If you are using a Gas Control Module, install it according to the instructions in the GCM manual.

11.) Connect a chamber pressure sensor to the port labeled PRESSURE on the rear of the system.

12.) Replace the top cover and secure with four screws.

CAUTION: THERE ARE TWO LEVER TYPE INTERLOCK SWITCHES MOUNTED ON THE RIGHT SIDE (AS VIEWED FROM THE FRONT) OF THE CHASSIS. WHEN REPLACING THE TOP COVER, BE SURE TO PULL THE RIGHT SIDE OF THE COVER SLIGHTLY OUT IN ORDER TO CLEAR THE SWITCH LEVERS AND AVOID DAMAGING THE INTERLOCK SWITCHES.

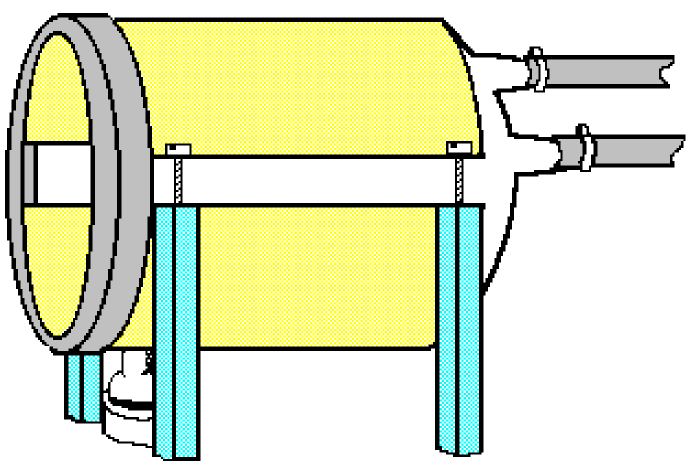
13.) Carefully insert the inner chamber into the outer chamber, orienting the slot perforations to the bottom of the chamber so that the four small glass knobs are in position to provide some space at the bottom between the inner and outer chamber sections.

14.) Close and latch the Plasmod door.

15.) Connect the POWER CORD on the back of the system to a voltage source.

CAUTION: BEFORE PLUGGING THE SYSTEM IN, MAKE SURE THAT THE VACUUM SWITCH, THE RF SWITCH, AND THE AC SWITCH ARE OFF.

16.) Pump exhaust should have an exhaust line that vents outside of the facility. Some of the more hazardous gases may require the use of an exhaust scrubber. After ensuring the exhaust line is connected properly, connect the VACUUM PUMP POWER CORD to a voltage source.



PROPERLY INSTALLED
6" CHAMBER

EQUIPMENT ORIENTATION

This section includes a general description of the plasma system as well as a more detailed description of the controls and indicators.

GENERAL DESCRIPTION

The Plasmod system is a tabletop plasma chemistry reactor designed to provide the scientific, educational and microelectronics community with plasma technology at a moderate cost. March is able to provide such capability by engineering a simple to operate instrument which can perform repeatable plasma chemical reactions. All controls are manual on the standard system. An optional Gas Control Module (GCM) may be used to automate the system.

The Plasmod instrument comes equipped with an internally housed solid state RF generator which generates an intermediate level RF signal at 13.56 MHz. The signal is transferred to a power amplifier, the output of which is filtered and coupled to an impedance matching network. Two variable capacitors provide fine tuning control for matching the output impedance of the RF generator to the capacitive load of the reaction chamber. The RF watt meter can be selected to read reflected or forward power to aid manual tuning.

The Plasmod is a small reactor which weighs under 45 pounds fully assembled. It consists of the solid state RF generator and associated tuning circuits, a vacuum system with a solenoid controlled valve, a constant feed gas supply system, and a reaction chamber which includes two semicircular electrodes and a two piece Pyrex or quartz chamber. An optional Gas Control Module can be added to control gas flow, monitor chamber pressure, and to automate the process. Automatic tuning can be added to fully automate the system.

RF GENERATOR

The solid state RF generator is a solid state crystal controlled oscillator designed to provide up to 150 watts of continuous wave 13.56 MHz (the FCC assigned frequency for this application) signal to the reaction chamber. Maximum power transfer from the power supply to the reaction chamber is accomplished by matching the output impedance of the amplifier to the input impedance of the reaction chamber. Two toggle switches(C1 and C2) provide manual tuning control for matching the 50 Ohm output impedance to the capacitive load of the reaction chamber. When the mismatch becomes excessive an audio assisted alarm sounds to indicate a de-tuned plasma.

VACUUM SYSTEM

The vacuum system includes the vacuum pump (purchased separately), the vacuum pump hose, the vacuum valve and the control circuitry. The vacuum valve is controlled in series with the RF generator switch to prevent RF power from coming on unless the chamber is evacuated.

GAS SUPPLY SYSTEM

Gas is supplied to the Plasmod via a gas delivery system located inside the reaction chamber. The delivery system is a glass tube sealed at its far end and perforated along its bottom surface. Connections to the delivery tube are fastened with special clips to prevent the possible leakage of atmospheric contaminants into the chamber.

REACTION CHAMBER

The standard reaction chamber sub-system consists of an upper and lower electrode and a two piece Pyrex or Quartz reaction chamber. These are open ended cylinders designed to fit into each other to form a closed chamber. The chamber is sealed with a flat silicone gasket which seats against a raised lip on the inner chamber. The gas delivery tube feeds through the back of the outer chamber section. This chamber section also provides connection to the vacuum hose by a glass tube joined at the front bottom of the chamber.

The inner chamber is perforated by a series of slots located on the bottom surface of the chamber. Four glass "feet" on the bottom of the inside chamber raise it off the inside surface of the outer chamber to provide a space between the two chamber sections. This arrangement provides for the best gas flow and results in repeatable, dependable processing.

A larger chamber (approximately 6" in diameter) is available as an option. This chamber consists of one fixed cylinder with a sealing gasket. A vacuum seal is established between the gasket and a lid located on the door of the instrument. When the door is closed, the chamber is sealed.

AUDIO ASSISTED TUNING (AAT)

The Plasmod features March's exclusive Audio Assisted Tuning and protection circuit. This circuit consists of a Sonalert alarm and its associated circuitry. If the generator to chamber impedance matching degrades the reflected RF power increases. When the reflected power exceeds the maximum allowable level, the Sonalert is activated to indicate potential damage to the RF generator. To eliminate the impedance mismatch, the operator must tune the system for a minimum reflected power reading which will silence the alarm. With the installation of optional auto tuning, the reflected power is constantly monitored and automatically kept at a minimum.

SPECIFICATIONS

The Plasmod system specifications are listed below.

Height	11.1 inches (28.2cm)
Width	12 inches (30.5cm)
Length	17 inches (43.2cm)
Weight	43 lbs
Chamber	Standard Chamber: Pyrex or quartz, 5.9" (15cm)L x 4.1" (10.4cm)D Optional chambers: Pyrex, 7.5" (19cm)L x 5.6" (14.2cm)D Quartz, 7.0" (17.8cm)L x 5.6" (14.2cm)D
RF Power	0 to 150 watts
RF Frequency	13.56Mhz

CONTROLS AND INDICATORS

This section describes the controls and indicators on the front and rear of the Plasmod system.

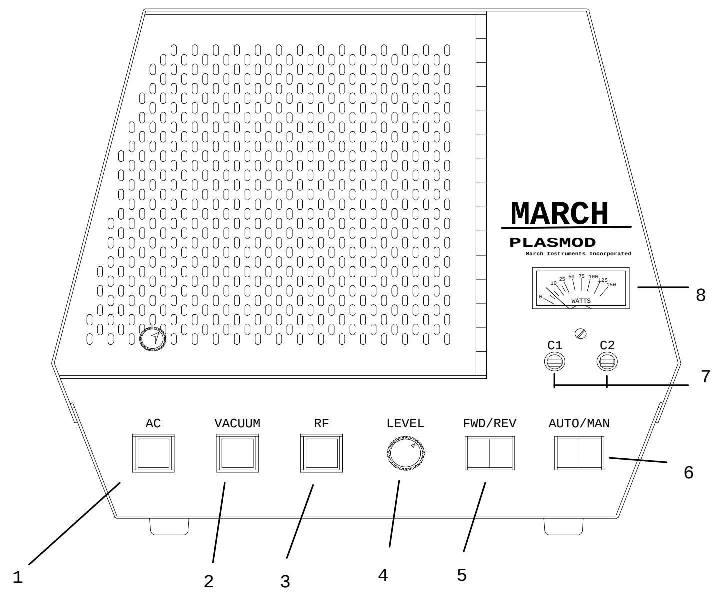


FIGURE 3.1

Figures 3-1 and 3-2 are illustrations of the location of the controls and indicators on the instrument.

1. **AC** - The AC power switch is a push-button lamp switch which is lit when the main power is on.

2. **VACUUM** - The vacuum switch is a push-button lamp switch which is lit when the chamber is under vacuum. In the on position the vacuum solenoid valve is open and the bleed solenoid valve is closed. When the switch is off, the vacuum solenoid valve is closed and the bleed solenoid valve is open, venting the chamber to atmospheric pressure.

3. **RF** - The RF power switch is a push-button lamp switch which is lit when the RF power is on.

4. **LEVEL** - The level control knob is a potentiometer which controls the RF power level.

5. **FWD/REV** - Toggles the meter display to indicate either forward power (FWD) or reflected power (REV) in watts. The selected mode of operation will be indicated by which side of the switch is illuminated. If the left side is illuminated the meter

indicates forward power. If the right side is illuminated the meter indicates reverse (or reflected) power.

6. **AUTO/MAN** - Selects either the manual tuning mode or if installed, the optional automatic tuning mode for RF power. The selected mode of operation will be indicated by which side of the switch is illuminated. If the left side is illuminated the unit is in auto tuning mode. If the right side of the switch is illuminated it is in manual tuning mode.

7. **C1/C2** - Manual switches for controlling the variable capacitors to manually tune the RF power. Used to minimize reflected power by matching the impedance of the RF generator and the chamber.

8. **RF Power Meter** - Indicates forward or reflected power in watts. The FWD/REV switch determines which parameter is monitored.

9. **AUTO/MAN** - Toggle switch for selecting automatic or manual mode of system operation (Auto mode only for use with GCM-200 or GCM-250).

10. **GAS IN** - For connecting incoming gas from cylinder or from Gas Control Module.

11. **PRESSURE** - Fitting for optional pressure transducer. Connects to pressure monitor on Gas Control Module.

12. **SONALERT ALARM/SILENCE** - The alarm switch is a toggle switch located on the back of the Plasmod. In the ALARM position, an alarm will sound when the RF is out of tune. In the SILENCE position, the alarm is disabled.

CAUTION: TURNING THE ALARM SWITCH TO THE “SILENCE” POSITION MAY ALLOW UNTUNED OPERATION TO OCCUR WITHOUT OPERATOR'S KNOWLEDGE. THIS COULD RESULT IN DAMAGE TO THE EQUIPMENT.

13. **7ASB** - 7 amp slow blow fuse.

14. **Voltage Select** - Small circuit board that allows the user to change the equipment voltage. With the power cord and fuse removed, read the voltage as indicated by the writing to the left on the side of the circuit board facing upward. If it is necessary to change the voltage, extract the circuit board and reinstall it so that the desired voltage rating is oriented to the left on the side of the board facing upward.

15. **Vacuum Connection** - The vacuum fitting on the rear of the Plasmod provides for connection to a vacuum pump.

16. **GCM** - 5 pin connector which connects the Gas Control Module to the Plasmod. This powers the GCM and engages the automatic sequencers.

17. **Fan Intake**

18. **Alarm Speaker**

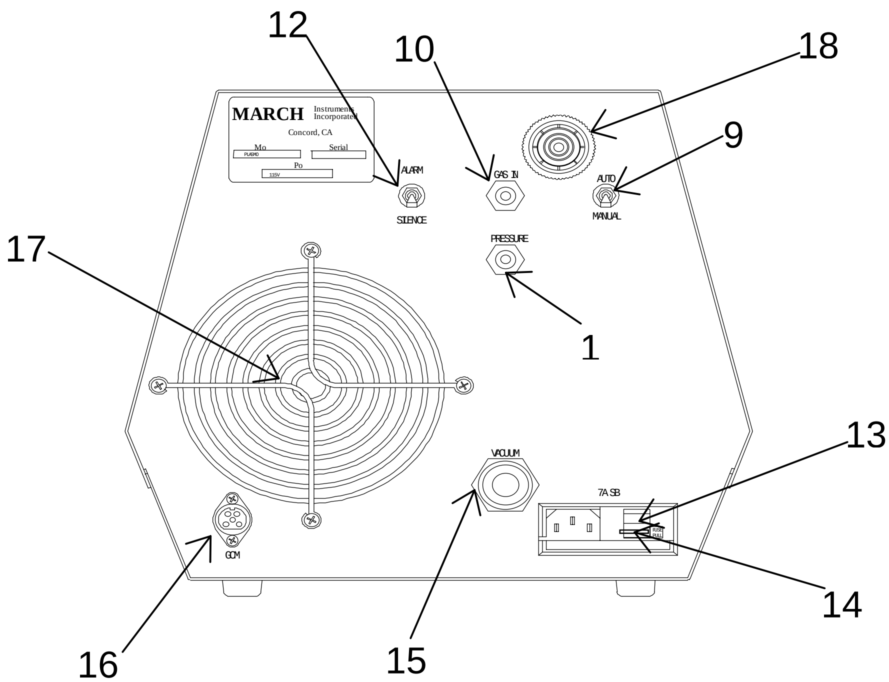


FIGURE 3-2.

THEORY OF OPERATION

This chapter gives an overview of plasma and plasma processes. It outlines the basic requirements to create a plasma and what variables are under operator control.

THE PLASMA PROCESS: AN OVERVIEW

A gas plasma consists of a collection of ions, free radicals, and electrons produced when a gas is transformed to a high energy, excited state by exposure to an energy source under the right physical conditions. Natural plasma examples include lightning, fire, and the Aurora.

Plasma treatment is a process by which the surface of a material is modified in some way through the actions of the dissociated molecular components of a gas. Because these components are in such a high energy state, they are very chemically reactive and can easily affect changes to the surface of materials. The changes that occur are complex and dependent on many variables including gas chemistry, process pressure, and the surface chemistry of the material being processed. A key advantage to plasma treatment is that only the surface (first several molecular layers) of the material is altered; the characteristics of the bulk material remain the same. The process occurs near ambient temperatures without employing toxic chemicals.

In etching and cleaning processes, unwanted material is removed from the surface of the substrate using a relatively high energy plasma. The process breaks the contaminant molecules into smaller pieces which volatilise and are then swept out of the chamber by the vacuum pump.

Surface activation processes work by altering the first several molecular layers of the bulk material through incorporation of chemical functional groups that increase the surface energy of the material. This leads to improvements in the adhesion and wettability of the treated material.

TYPICAL PLASMA PROCESS

Plasma processing in the Plasmod is accomplished through the use of a low pressure, RF induced gaseous discharge. The material or specimen is loaded into the reaction chamber. The chamber is evacuated to a mild vacuum (.15-.2 torr) by a mechanical vacuum pump. A process gas is drawn through the chamber over the specimen increasing the chamber pressure to between .2 - 1.2 torr, depending on the application. RF power is applied to the chamber at a frequency of 13.56Mhz. This excites the process gas atoms or molecules and dissociates them into chemically active species. These species are very short lived and recombine to form the original gas molecules as soon as they are carried out of the reaction chamber. The plasma byproducts (unused process gas and volatilised material from the sample surface) are carried away by the vacuum.

BASIC ELEMENTS OF PLASMA TREATMENT

To plasma treat a sample in the PLASMOD system, the basic steps are:

1. Place the material to be treated onto the shelf.
2. Place the shelf within the vacuum chamber.
3. Seal the vacuum chamber.
4. Pump the vacuum chamber down to a low, preset pressure level.
5. Introduce a process gas or gases into the chamber.
6. Apply RF energy to the low pressure gas in the chamber to light the plasma.

To end the process:

1. Stop applying RF energy to the chamber.
2. Stop the flow of process gases.
3. Bleed the chamber back to atmospheric pressure.
4. Open the vacuum chamber.
5. Remove the treated material from the chamber.

These steps are flow charted on the next page.

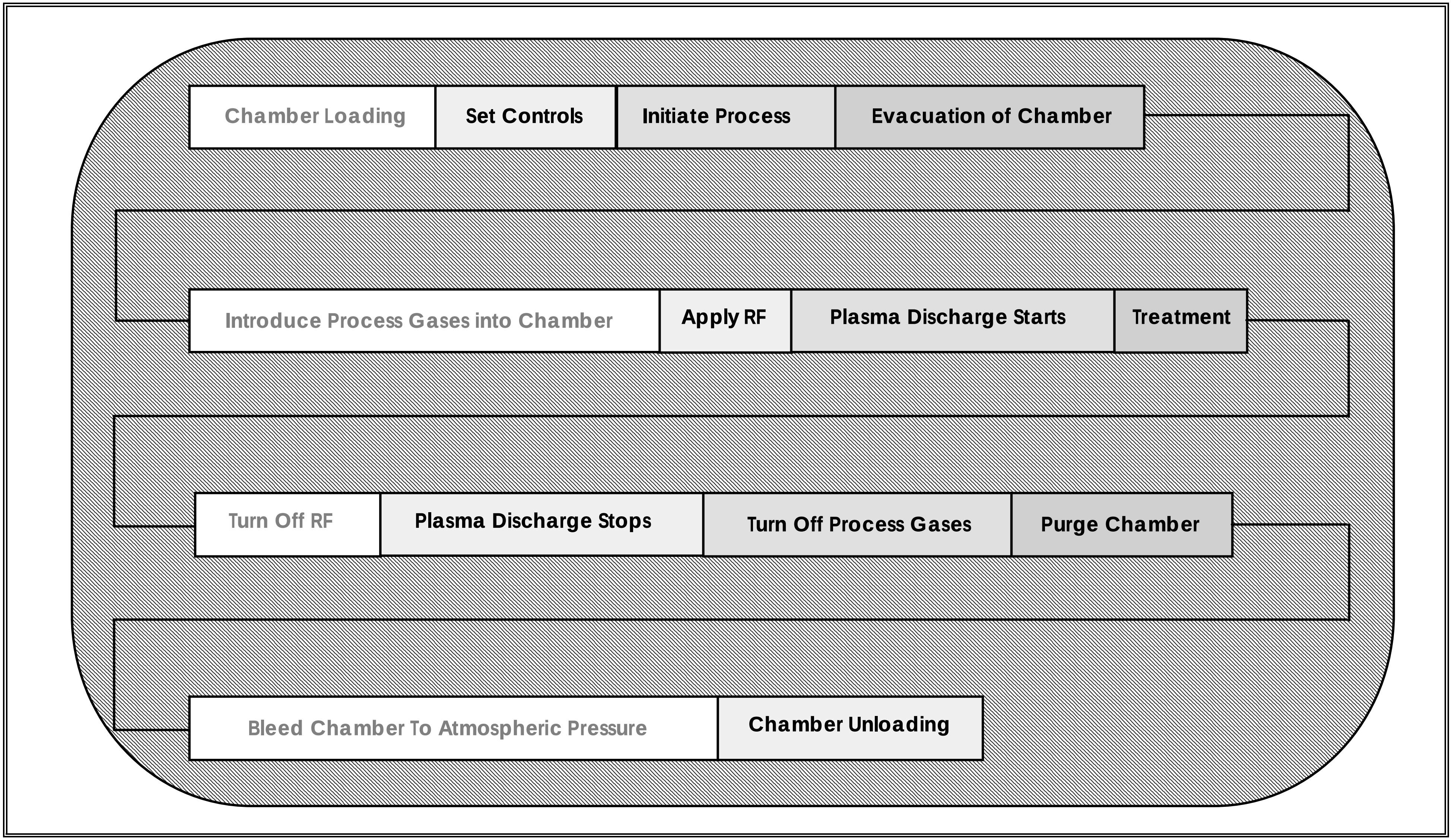
CAUTION: THE CHAMBER WILL BECOME VERY HOT DURING SOME PROCESSES. EXERCISE CAUTION TO PREVENT BURNS.

In order to develop and optimize a plasma process for a given material, the operator has the ability to alter the following parameters:

- Process gas(es) selected for use.
- Flow rate/pressure of selected gas(es).
- Amount of RF energy applied to the vacuum chamber.
- Amount of time material is exposed to the plasma.

Process pressure, RF power, and treatment time are the primary factors that affect the intensity of the treatment. For example, a high energy treatment would be run under conditions of relatively low pressure, high power, and long treatment time. Conversely, a low energy treatment would be run under conditions of relatively high pressure, low power, and a short treatment time.

Since every material has different treatment requirements and many factors need to be taken into account, it is difficult to say what type of treatment will give the desired results. A general rule would be that energetic processes are better for cleaning and etching applications; more moderate processes are better for surface activation applications.



Plasma System Operational Sequence

OPERATION

This section describes the procedures required for operation of the Plasmod system. If the Plasmod is being operated with a Gas Control Module, follow the operating instructions in the GCM manual.

The basic operation of the Plasmod consists of loading the object to be processed, evacuating the reaction chamber, introducing the process gas, and applying the RF power to induce a plasma. The RF power output impedance must be matched, either manually or automatically, to the plasma chamber impedance for the best power transfer. Upon completion of the process, the RF power and process gas flow are turned off, the vacuum valve is closed, and the chamber bleeds back to atmospheric pressure.

For initial startup of the Plasmod, proceed as follows:

1.) Turn off all switches before plugging the unit in (Buttons for AC, VACUUM, and RF should not be pressed in).

2.) Plug in the vacuum pump.

3.) Turn on main power by depressing the AC push-button. The switch/lamp should light red.

4.) Open the door. Ensure that the inner chamber is fully extended into the outer chamber.

5.) Push in the VACUUM switch. Gently lift the chamber slightly and press the inner chamber in to make sure that the chamber is seated and undamaged as a result of the application of vacuum. For the optional 6" diameter chamber, ensure that the door is fully closed to seal the chamber.

6.) Close the door and wait approximately two minutes for the chamber to pump down. The pressure should reach 0.15 torr although this cannot be confirmed unless using a Gas Control Module.

7.) Turn on gas and set to the desired flow rate. If a Gas Control Module is not used, this is best controlled by using a needle valve or similar device.

8.) Make sure that the AAT Alarm is in ALARM position (item 12, Figure 3-2, page 18).

9.) Toggle the AUTO/MAN switch (item 6, Figure 3-1, page 16) to the MAN position for manual tuning of RF power (If Auto tuning was not purchased).

10.) Turn on RF power (item 3, Figure 3-1) by pressing the RF button. The audible alarm will sound.

11.) Toggle the FWD/REV switch (item 5, Figure 3-1) to the REV position so that the meter is reading reflected power.

12.) Tune the RF matching network for minimum reflected power by toggling C1 and C2. First toggle C1 until a minimum reflected power reading is obtained. Then toggle C2. Alternate C1 and C2 until the reflected power is minimized.

13.) Toggle the FWD/REV switch to the FWD position and turn the RF level knob to the desired power.

14.) Re-tune using the procedure in step 12.

15.) When the Plasmod is tuned for minimal reflected power, allow the unit to "burn in" for about half an hour before using it. This will eliminate any contamination which might be present in the chamber. Air, Oxygen, or Argon process gas can be used for "burn in".

With the exception of the “burn in”, the general steps outlined above should be used whenever the system is operated.

To terminate the process:

1.) Turn Level control fully counter-clockwise.

2.) Toggle the RF switch off.

3.) Shut off the gas.

4.) Toggle the vacuum switch off. The chamber will bleed to atmospheric pressure.

The instrument can now be loaded and a process performed.

TUNING THE RF MATCHING NETWORK

The Plasmod Plasma System utilizes an L-C tuning network to ensure maximum transfer of energy into the chamber. The unit is equipped with a manual tuning system comprised of motor driven air capacitors which are positioned by the operator to achieve minimum reflected power during processing. This positioning is accomplished through front panel mounted switches. Additionally, an optional Auto tuning system may be installed. The Auto tuning option adds circuitry which continually monitors the forward-to-reverse power ratio during processing and positions the air capacitors for optimum power transfer to the chamber.

WARNING*: *REFLECTED POWER LEVELS THAT BECOME EXCESSIVE CAN CAUSE DAMAGE TO, OR FAILURE OF, THE RF POWER GENERATOR. IT IS VITAL THAT REFLECTED POWER BE MONITORED AND KEPT TO A MINIMUM LEVEL DURING OPERATION.

Manual Tuning

- Toggle the front panel AUTO/MAN switch to MAN position.
- Toggle C1 and C2 switches to minimize reflected power.
- Reflected power value is displayed on the RF power meter when the FWD/REV button is toggled to REV.

Automatic Tuning (If installed)

- Toggle the front panel AUTO/MAN switch to the AUTO position.
- Reflected power value is displayed on the RF power meter when the FWD/REV button is toggled to REV.
- Monitor reflected power during the plasma process to ensure proper operation of Auto tuning.

SERVICE AND MAINTENANCE

This section gives information on the warranty and details on servicing the equipment. Recommended maintenance and part replacement procedures are outlined. A trouble shooting guide is also included.

WARRANTY

1. This March system is guaranteed to be free of defects in workmanship and components. This warranty covers labor for a period of ninety (90) days and parts for a period of one (1) year, with the exception of ceramics, glass, seals, lubricants, and consumable parts such as rollers, bearings etc.

2. The exclusive remedy for any breech of this warranty is as follows: March Instruments, Inc. will furnish without charge, repairs to or replacement of those parts proven to be defective in material or workmanship. March Instruments, Inc. will issue a Return Authorization number for the defective parts. The customer will give March Instruments, Inc. a Purchase Order number of a dollar amount to cover the cost of these parts. Once the system is operational the customer will return all defective and/or unused parts back to March Instruments, Inc. with the Return Authorization number on the outside of all packages. Once these parts are received a credit will be given minus any shipping or transportation costs. No claim may be made for any incidental or consequential damages.

3. All transportation and shipping charges shall be borne by the customer.

4. March Instruments, Inc. will inspect the equipment and decide upon such repairs or replacement as are necessary. The customer will be notified of any charges incurred that are not covered by this warranty prior to undertaking those repairs.

5. Any customer modification of this equipment, or any repairs undertaken without prior written consent of March Instruments, Inc. shall render this warranty void.

6. This warranty is expressly in lieu of all warranties, expressed or implied, including implied warranty of merchantability or fitness for a particular purpose unless otherwise agreed to in signed correspondence from March Instruments, Inc. March Instruments, Inc. shall not be responsible for any damage caused by improper installation, use, servicing or testing of equipment.

SERVICING

If a unit is to be returned to March Instruments for service or for any other reason, the following procedures must be followed:

- Obtain a Return Authorization number (RA) through the March Customer Service Department, (925) 827-1240. Display this number on your shipping label. A unit received without an RA number visible will be rejected.
- Re-pack the system in its original shipping container. If this is no longer available, take special precautions to avoid damage to the glass chamber sections and other fragile components. DO NOT SHIP ANY GLASS INSIDE OF THE INSTRUMENT. An approved shipping container may be purchased from March Instruments.
- If the system is under warranty, the only charges are shipping costs. If the system is out of warranty, a purchase order will be required and you will be billed for all parts and service.

If you have any questions, do not hesitate to call the March customer service department.

RECOMMENDED SPARE PARTS

The following is a list of recommended spare parts for the standard Plasmod system.

March Part Number	Quantity	Description
002-1001	1	Standard Inner Chamber, 4" Pyrex
004-7001	2	O-Ring, 4" Chamber Jar Gasket
004-7002	2	O-Ring, 7/16" I.D.
004-7020	1	Hose, Red Silicone
004-8610	8	Screw, Nylon 6-32 X 1.00" PHP
004-9005	4	Standoff, 5/16" Nylon
011-1010	2	Fitting, Clip Lock Male/Female
008-1032	8	Lamp, Incandescent
009-1023	1	Valve, Vacuum, 110V
007-8002	2	Air Capacitor Coupler
008-1033	2	Fuse, 7A 250V SLO-BLO
009-1021	1	Valve, Solenoid, 110V
011-1009	2	Fitting, Clip Lock Tube 10236

All above parts are available in a single kit, Part Number 99-099-001.
Units with 4" Quartz chamber - Kit Part Number 99-099-002*
*Only difference with kit is the 4" Quartz chamber (Part number 002-1003)

Units with 6" Pyrex chamber - Kit Part Number 99-099-006**
**Only difference with kit is the 6" Pyrex chamber (Part number 002-1011) and Chamber Jar Gasket (Part number 004-6050)

Units with 6" Quartz chamber - Kit Part Number 99-099-007***
***Only difference with kit is the 6" Quartz chamber (Part number 002-1013) and Chamber Jar Gasket (Part number 004-6050).

PLASMOD USER MAINTENANCE

User-performed maintenance required for Plasmod Plasma System is minimal. However, regular attention to the suggested maintenance tasks listed below will help to ensure proper operation of the system. To ensure maximum performance and process repeatability, the following items should be checked at regular intervals.

CLEANING THE CHAMBER

The chamber should be cleaned periodically. The cleaning schedule will depend on frequency of use, type of materials processed, and choice of process gas.

The inner chamber will require more frequent cleaning than the outer portion. For light contamination, running an oxygen plasma (or air if oxygen is not available) for 20 minutes should be enough to clean the chamber. For more difficult contaminants such as inorganic films and residues, use standard laboratory cleaning procedures. Remove the inner chamber and wash the chamber with a test tube brush and a good laboratory detergent. If this is not effective, it will be necessary to use an oxidizing agent. Refer to the Handbook of Chemistry and Physics for the proper agent. The outer chamber will also require a similar procedure but requires cleaning about half as frequently as the inner chamber.

VACUUM PUMP OIL

Many of the problems with the vacuum system are associated with the vacuum pump oil. It is important that the oil condition be checked periodically to verify that it is at the proper level and free of contaminants. Dirty or insufficient oil can result in poor vacuum pump performance. Dirty oil can also lead to possible chamber contamination due to the increased vapor pressure back streaming into the chamber from the contaminated oil. Refer to the pump manual for explicit instructions on changing oil and all other pump procedures.

CAUTION: THE PUMP OIL IS A SKIN AND EYE IRRITANT. ALWAYS USE EYE PROTECTION AND APPROVED PERSONAL PROTECTIVE EQUIPMENT WHEN CHANGING THE PUMP OIL.

Some plasma processes may create a larger degree of pump oil contamination than others. Additional personal protective equipment may be necessary in some cases. The end user of this equipment should conduct industrial hygiene sampling in accordance with NIOSH, or other nationally recognized standards or test procedures, during the changing of the pump oil. Do not allow this pump oil to flow down the sewer drain.

Pump oil should be changed at least once a year. If the system is getting a lot of use and the process being used creates a large amount of contamination, the oil may need to be changed as often as every two months. If the pump oil appears visually dirty, it needs to be changed. Check the pump oil at least once a month. A competent technician should be able to change the pump oil in about one hour.

PLASMOD SYSTEM MAINTENANCE CHECKLIST

DATE:									
CHAMBER CLEANING- INNER CHAMBER									
CHAMBER CLEANING- OUTER CHAMBER									
PUMP OIL CHECK									
PUMP OIL CHANGE									

SYSTEM TROUBLESHOOTING

The following troubleshooting section is designed to help the operator identify and solve the most common instrument problems. Any major equipment repairs should be performed by March service engineers. If you are unable to identify a problem, call the March service department.

LOCATING VACUUM LEAKS

The procedure outlined below is for locating and fixing vacuum leaks. A vacuum leak will cause the plasma to have a redder shade than usual due to the nitrogen from the air leaking into the chamber. If using a Gas Control Module (GCM), a leak may be present if the system will not pump down below .15 torr.

1.) If the system has a Gas Control Module, attach the vacuum gauge directly to the vacuum pump to determine if the gauge is faulty. This will require a special adapter of some type since the vacuum gauge connector is of different diameter than the vacuum hose. The vacuum gauge is the port labeled PRESS on the GCM.

2.) Check to see if the vacuum port O-ring at the base of the outer chamber is sealing properly. Replace the O-ring if necessary.

3.) Check that the chamber gasket to see if it is in good condition and is sealing properly.

4.) Tighten all external fittings on the Plasmod and on the GCM.

5.) Check the clip-lock fittings for the process gas and pressure gauge lines at the rear of the chamber. Disconnect and check for dirt in the fitting, then reconnect using a small amount of vacuum grease.

6.) Normally, when the VACUUM button on the Plasmod is on, the vacuum solenoid is open. When the VACUUM button is off, the solenoid is closed. If this solenoid is faulty or leaks, there will be a constant vacuum. A loud hissing noise is a symptom of this problem. To confirm a faulty valve, turn off the VACUUM switch on the Plasmod, leave the vacuum pump on and remove the inner chamber. If there is a slight vacuum at the vacuum port, the solenoid must be replaced.

7.) If using a GCM, it is possible to locate a very small leak by squirting all external fittings and sealing ports, one at a time with alcohol. When alcohol is poured over the connection that is leaking, the pressure indicator on the GCM should rise slightly as the alcohol vapor is sucked into the chamber.

TROUBLESHOOTING

Action	Normal	Abnormal	Course of Action/Possible Cause
Push AC button.	AC button is lit and fan is running.	AC button is not lit but fan is running. AC button is lit but fan is not running. AC button is not lit and fan is not running.	A.) Replace pilot lamp. A.) Fan is burned out. A.) Make sure system is plugged in. B.) Check fuse in rear of system.
Push VACUUM button.	Chamber is evacuated.	Chamber has not evacuated and pump is running.	A.) Check pump. Remove the vacuum line from the rear of the Plasmod and determine if the pump has suction. B.) Check vacuum connections. Tighten connections and replace seals as necessary. C.) Check vacuum and bleed valves.
Push RF button (with chamber evacuated).	Indication on RF Power Meter.	No indication on RF Power Meter.	A.) Check door and external cover safety interlocks. Make sure door is closed properly and external cover is attached snugly. B.) Defective RF generator.

TROUBLESHOOTING (Cont.)

Action	Normal	Abnormal	Course of Action/Possible Cause
Turn RF level clockwise to maximum (With chamber evacuated and RF button pushed in).	Meter indicates 150 watts.	Low or no indication.	A.) Check door and external cover safety interlocks. Make sure door is closed properly and external cover is attached snugly. B.) Check AUTO/MAN switch on rear of Plasmod to ensure it is in manual position. C.) Make sure system is tuned for minimum reflected power. D.) Defective RF generator.
Adjust C1 and C2 toggles for minimum reflected RF power reading on meter.	Uniform plasma in chamber.	No plasma or non-uniform plasma.	A.) Check for vacuum leaks (see procedure on page 29). B.) Change process power and/or gas flow slightly.

TUNING AND REPLACEMENT PROCEDURES

This portion of the manual provides information necessary to perform Maintenance, Fault Isolation, and Removal and Replacement of subject assemblies in the RF system and optional Autotuning system. It also details Adjustments required for proper operation. The SEMI S2-93 level of Hot Work is listed where applicable.

CAUTION: THESE CAUTIONS ARE APPLICABLE TO THE ACTIONS DETAILED ON THE FOLLOWING PAGES:

- **LINE VOLTAGE HAZARD EXISTS WHENEVER INTERNAL WIRING IS EXPOSED.**
- **RADIO FREQUENCY VOLTAGE AND EXPOSURE HAZARD EXISTS WHEN THE EXTERNAL COVER IS REMOVED.**
- **HIGH TEMPERATURE BUILDUP WILL OCCUR ON SOME ELECTRONIC COMPONENTS AND HEAT SINKS INSIDE THE EXTERNAL COVER DURING OPERATION.**

Fundamentals of Operation

Autotuning circuitry consists of an RF Phase and Magnitude sensing device, a Tuning Controller and associated wiring. The RF Phase and Magnitude sensing device measures forward and reverse power magnitudes and phase relationships of the RF as it is applied to the tuning network. Phase of the RF power is measured at two points; magnitude is similarly measured. The measurement at one point is compared to that at the other point. If any difference exists, it is output as a voltage to the amplifiers on the tuning controller printed circuit board. Here it is amplified to a level sufficient to drive the tuning motors which control the positioning of the variable capacitors of the tuning network. When these capacitors are properly positioned, there will be minimal standing waves in the RF transmission lines which will result in little or no difference in the value of the phase or magnitude of the RF when measured at the two sensing points. This, in turn, results in a zero volt difference between these points. No drive voltage for the tuning motors is created and the tuning capacitors will retain their position until the tuning degrades. When this occurs, the phase/magnitude sensor will detect the difference, and express it as a voltage, which will be amplified by the tuning controller amplifiers for application to the tuning capacitor motors and drive the tuning capacitors to values capable of most effectively coupling the RF power to the plasma.

When the Automatic/Manual Tuning switch on the control panel of the unit is placed in the AUTO position, the output of the amplifiers on the tuning controller PCB are applied to the tuning capacitor positioning motors. When the same switch is placed in the MANUAL mode, the operator controls tuning by applying a drive voltage of + or - 15V to the individual drive motors through switches C1 & C2. By monitoring reverse (or reflected) power via the RF Meter on the control panel of the unit the operator can manually tune for a minimum reverse power level.

Maintenance

No regular maintenance is required.

Fault Isolation

The following procedure is to be used in determining the cause of problems with the components in the RF system.

Hot Work Level 4

Required Materials:

- Multimeter
- Standard assortment of hand tools

Procedure

1. Using standard operational procedures and process parameters, run plasma system through normal operational cycle.
2. Observe forward power indication on RF Level meter. It should be possible to obtain an indication of the maximum level that the RF generator installed in the system is capable of achieving. The unit should be manually tuned for minimum reverse power as indicated on the RF Level meter. If it is not possible to manually tune the unit for a reverse power level of 5 watts or less, proceed no further. Contact March Instruments to arrange for factory reconfiguration of the tuning network.
3. Once unit is manually tuned properly, place the control panel mounted tuning mode selection switch in the AUTO position. The system should maintain approximately the same low value of reverse power as indicated on the RF level meter. The unit may temporarily go out of tune when switching from Manual to Automatic tuning but will return to a tuned condition after a few seconds. This is normal and expected. If the unit remains out of tune for more than 30 seconds, return to manual tuning and tune unit or turn off RF to prevent damage to the power amplifier.
4. Increase and decrease chamber pressure by adjusting gas flow. The unit should maintain approximately the same low value of reverse power as indicated on the RF level meter.
5. Increase and decrease RF power level by RF generator output. The system should maintain approximately the same low value of reverse power as indicated on the RF level meter.
6. Place the control panel mounted tuning mode selection switch in the MAN position. Actuate C1 & C2 to detune the unit. This is indicated by a dimming or extinguishing of the plasma glow and an increase in the value of reverse power as indicated on the RF level meter or a sounding of the tuning alarm.
7. Once unit is detuned, place the control panel mounted tuning mode selection switch in the AUTO position. The system should tune to and maintain the original low value of reverse power as indicated on the RF level meter.
8. If the unit passes all of the steps detailed above, it is operational. If it fails any of those steps, continue with steps listed below.
9. Ensure unit power has been turned off. Remove AC Line power cord if possible.
10. Remove external cover.

11. Visually inspect RF Tuning Controller PCB for evidence of burning, shorting or damaged components. If any evidence of damage is noted, repair or replace the printed circuit board or failed components on that board. Inspect all wiring and connections for mechanical and electrical integrity. Repair as necessary.
12. To determine proper output from Phase/Mag module, disconnect wiring harness from Phase/Mag module and connect test equipment as shown in Diagram 1. Set meter to 2 volt scale (or closest setting).

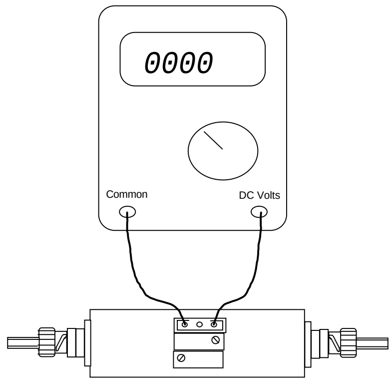


Diagram 1.

NOTE: IT IS NECESSARY TO DETERMINE WHICH PIN ON THE PHASE/MAG MODULE IS AT GROUND POTENTIAL. WHILE IT WILL ALWAYS BE ONE OF THE TWO OUTSIDE PINS, A SMALL PERCENTAGE OF PHASE/MAG MODULES WERE CONSTRUCTED WITH THE NORMAL PIN ASSIGNMENT(AS ILLUSTRATED IN THE ABOVE AND FOLLOWING DIAGRAMS) REVERSED. TO DETERMINE GROUND PIN ASSIGNMENT, CHECK FOR CONTINUITY BETWEEN ETCHER CHASSIS AND OUTSIDE PINS. IF PIN ASSIGNMENT IS REVERSE OF THAT ILLUSTRATED, THEN REVERSE MULTIMETER CONNECTIONS TO MATCH.

13. Reconnect AC power cord if removed.
14. Using standard operational procedures and process parameters, run plasma system through normal operational cycle.
15. Allow unit to warm up for at least one minute before taking readings.
16. Multimeter should indicate a -.5 volt to +.5 volt swing when adjusting lower potentiometer from one end of it's travel to the other. If this range cannot be obtained, replace the Phase Magnitude module. See Adjustment procedures (page 36) for proper setting of potentiometers.
17. Turn off RF power.

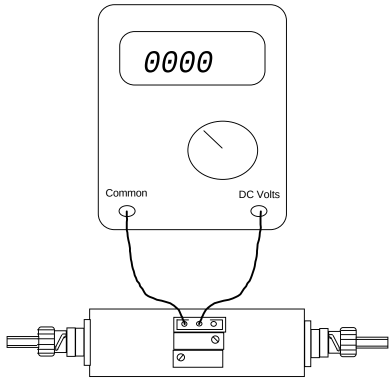


Diagram 2.

18. Connect test equipment as shown in Diagram 2. Set meter to 2 volt scale (or closest setting).
19. Using standard operational procedures and process parameters, run plasma system through normal operational cycle.
20. Multimeter should indicate a -.5 volt to +.5 volt swing when adjusting upper potentiometer from one end of it's travel to the other. If this range cannot be obtained, replace the Phase Magnitude module. See Adjustment procedure (page 36) for proper setting of potentiometers.
21. If output of Phase/Magnitude Module is correct, check inputs to and outputs from Tuning controller PCB. Inputs on J1-1 & J1-2 should be equivalent to outputs from Phase Magnitude module. Outputs of Tuning Controller, measured at IC1, pins 1 & 7, should be equivalent to outputs from Phase Magnitude module amplified by up to a factor of 50. Other Tuning Controller inputs to test include:

Location	Voltage
Connector J1 Pin 3	GROUND
Connector J1 Pin 6	GROUND
Connector J1 Pin 7	+15 VDC
Connector J1 Pin 8	-15 VDC

22. If inputs to the Tuning Controller PCB are correct, yet outputs are incorrect, replace Tuning Controller PCB.
23. If unit will tune in one mode but not the other, and outputs are correct from both Phase/Magnitude module and Tuning Controller PCB, check tuning mode selection switch (marked AUTO MAN) for continuity.

<u>Removal and Replacement of the Phase Magnitude Module</u>

The following lists the steps necessary for the removal and replacement of the Phase Magnitude module.

Required Materials:

- Standard assortment of hand tools

Procedure

1. Ensure unit power has been turned off and the power cord disconnected.
2. Remove system's external cover.
3. To remove Phase Magnitude module, disconnect wiring harness from Phase/Magnitude module by removing connector plug from socket.
4. Disconnect RF cable from both sides of Phase/Magnitude module by removing BNC connector plugs from connector sockets.
5. Loosen screws securing Phase/Magnitude module to chassis of unit.
6. To reinstall, reverse steps 2 through 5 above.

Adjustment of the Phase/Magnitude Module
The following lists the steps required to adjust the Phase/Magnitude module.

Hot Work Level 4

Required Materials:

- Multimeter
- Standard assortment of hand tools

Procedure

1. Remove system external cover.
2. Using standard operational procedures and process parameters, run plasma system through normal operational cycle.
3. Observe forward power indication on RF Level meter. It should be possible to obtain an indication of the maximum level that the RF generator installed in the system is capable of achieving. The unit should be manually tuned for minimum reverse power as indicated on the RF Level meter. If it is not possible to manually tune the system for a reverse power level of 5 watts or less, proceed no further. Contact March Instruments to arrange for factory reconfiguration of the tuning network.

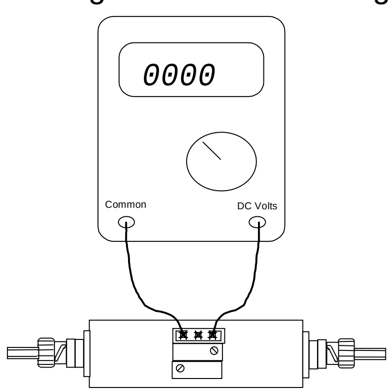


Diagram 3.

NOTE: THE RF GENERATORS USED WITH MARCH PLASMA SYSTEMS ARE EQUIPPED WITH CUTBACK CIRCUITRY TO PREVENT DAMAGE IN CASE OF SEVERE IMPEDANCE MISMATCHES. AS THE MISMATCH BECOMES MORE SEVERE, FORWARD POWER IS CUT BACK TO PREVENT DANGEROUS CURRENT AND VOLTAGE LEVELS (WHICH COULD CAUSE FAILURE OF THE POWER AMPLIFIER) FROM BUILDING UP.

4. Turn off RF power.
5. To adjust output from Phase/Mag module, disconnect wiring harness from Phase/Mag module and connect test equipment as shown in Diagram 3. Take care to avoid physical contact. Set meter to 2 volt scale (or closest setting).
6. Turn on RF power.
7. Taking care not to come into contact with any RF transmission line, tuning network component, or chamber electrode, adjust the lower potentiometer on the Phase/Mag module so that the Multimeter indicates zero volts (+/-5 millivolts).
8. Turn off RF power.
9. Connect test equipment as shown in Diagram 4. Set meter to 2 volt scale (or closest setting).

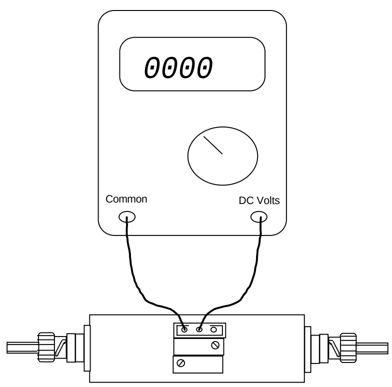


Diagram 4.

10. Turn RF on.
11. Adjust the upper potentiometer on the Phase/Mag module so that the Multimeter indicates as closely as possible to zero volts (+/-5 millivolts).
12. Turn off RF power.
13. Repeat steps 5-12 above until both pins on the Phase/Mag module indicate as closely as possible to zero volts (+/-5 millivolts).
14. Turn off unit power.
15. Disconnect Multimeter and reattach wiring harness to Phase/Mag module.
16. Test unit for proper operation as detailed in Fault Isolation, page 34, steps 1 through 8. If unit does not pass these tests, recheck adjustment and repeat if necessary.
17. When adjustment is complete, replace external cover.

APPENDIX

The appendix is a collection of information on some of the elements of plasma processing with the Plasmod equipment. Specific instructions on process development for etching applications are included.

PROCESS DEVELOPMENT-ETCHING

Etching processes can be controlled by the operator of the equipment to achieve desired characteristics including:

- Etch Rate.
- Uniformity.
- Anisotropy.
- Selectivity.

Other associated characteristics can be controlled as well, including:

- Process Heat.
- Ion Exposure.

Control is achieved through selection of:

- Process Gas.
- Process Gas Flow.
- RF Power Level.
- Chamber Pressure.
- Process Cycle Time.

The matrix on the following page is intended as a general guideline to help the operator develop an etching process by manipulating the system variables. It must be noted that the plasma etching process is extremely complex and is not easily characterized. In offering this information, March Instruments makes no claim as to it's applicability in tailoring operator controllable parameters to achieve specific etch characteristics. It is offered only to illustrate how altering an operator controllable parameter might effect an etch characteristic.

	Gas Choice	Gas Flow	RF Power	Process Time	Pressure	Chamber Loading
Etching Characteristics:						
Uniformity Increased	Yes	+/-	+/-	No Effect	+/-	-
Uniformity Decreased	Yes	+/-	+/-	No Effect	+/-	+
Etch Rate Increased	Yes	+/-	+	+	+/-	-
Etch Rate Decreased	Yes	+/-	-	-	+/-	+
Anisotropy Increased	Yes	+/-	+	-	-	Unknown
Anisotropy Decreased	Yes	+/-	-	+	+	Unknown
Selectivity Increased	Yes	+/-	+/-	No Effect	+/-	Unknown
Selectivity Decreased	Yes	+/-	+/-	No Effect	+/-	Unknown
Heat Build-up Increased	Yes	-	+	+	-	+
Heat Build-up Decreased	Yes	+	-	-	+	-
Ion Exposure Increased	Yes	+/-	+	+	+	Unknown
Ion Exposure Decreased	Yes	+/-	-	-	-	Unknown
Process Cycle Time Increased	Yes	+/-	-	+	+/-	+
Process Cycle Time Decreased	Yes	+/-	+	-	+/-	-

(+) =Increase value of parameter for desired change (+ or -) = Value of parameter can be increased or decreased for desired change

(-)=Decrease value of parameter for desired change

AVOIDING PROCESS GAS LINE CONTAMINATION

Process gas lines can be contaminated with air whenever the connection between the gas source and the plasma system is broken. This occurs when changing gas cylinders or flowrators, or when swapping gas lines.

Air contamination in gas lines displaces the desired process gas. This can result in inconsistent processing results and/or poorly treated product. This becomes especially critical in the smaller systems due to the small size of the flowrators (the low flow rates prevent air contamination from being flushed out of the lines quickly).

PREVENTIVE MEASURES

In order to avoid contaminating the lines, March recommends the following preventive steps.

Swapping Gas Lines:

When gas lines are swapped, no contamination will result as long as the gas connectors are "quick connect". If quick connects are not used, a needle valve should be in place which can be closed to isolate the gas line.

Changing Flowrators:

When changing flowrators, always be sure to first isolate the gas line by removing the "quick connect" or closing the needle valve.

Changing Gas Cylinders:

1) Close valve on gas cylinder.
2) Close valve on gas regulator to isolate gas line.
3) Disconnect gas cylinder from gas regulator.
4) Connect new cylinder to regulator.
5) Open valve on gas cylinder.
6) Open valve on gas regulator.

Gas Line Integrity:

Take care to insure that gas lines do not leak. Gas line integrity can be confirmed simply by opening the valve on the gas cylinder then quickly closing it again. If the pressure reading on the regulator drops within one minute, there is a substantial leak that may result in air contamination.

Gas leaks can be located using a soap/water solution (commercially available under the brand name Snoop). With the gas cylinder and regulator valves open, inundate areas of suspected leakage. Soap bubble formation indicates a gas leak.

CONSUMABLES

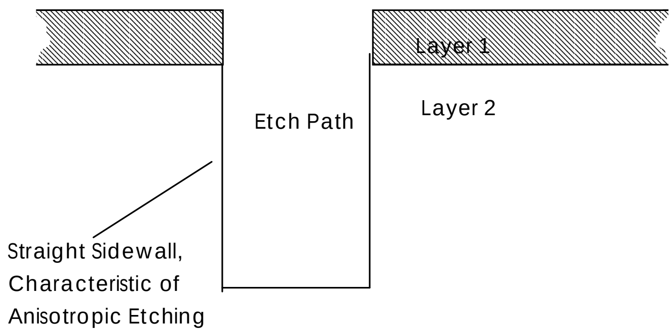
The fluorinated pump oil (Krytox) is the only consumable used in the system. This pump oil can become corrosive after being exposed to certain process gases. Always wear approved personal protection equipment (eye protection and rubber gloves) when changing the pump oil. Waste oil and any dirty rags generated during maintenance should be considered hazardous waste. It should never be dumped down the drain. Instead, place the oil in a corrosion proof waste container and dispose of the waste container at an EPA certified waste disposal company when full.

The Material Safety Data Sheet has been included in the back of the manual for reference.

GLOSSARY

The following lists definitions of commonly used terms in this manual.

Anisotropic: Etching that is directional in it's action with characteristic etch path side walls that are perpendicular to the electrode plates of the etcher. Characteristic of etching applications where the preservation of underlying material is desirable. Typical of reactive ion etchers(RIE).



Auto tuning System: An optional system that will automatically tune the RF matching network for minimal reflected power so that there is optimal power transfer to the chamber.

Base Pressure: The pressure at which the plasma process begins. The lower the Base Pressure level, the less impurities will be present in the chamber when the process gas is introduced. By evacuating the chamber for a longer or shorter period of time at the commencement of the process cycle, more or less of the room air and water vapor present in the chamber will be pumped out before the process gas is introduced. Also referred to as **Process Threshold Pressure**.

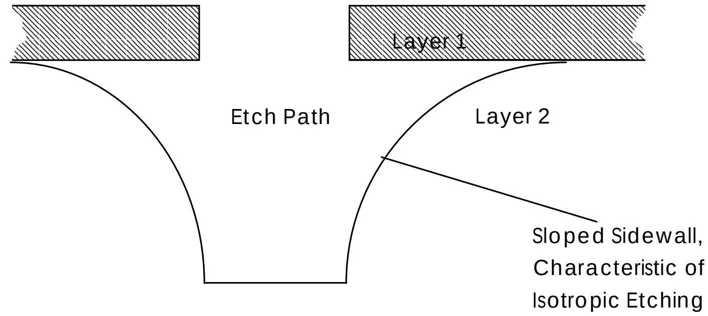
Endpoint: The point at which a material has received satisfactory treatment. Most commonly used in reference to cleaning processes.

Etch Rate: The rate at which material is removed during exposure to plasma. Often given as a value of Angstroms per minute.

Forward Power: The amount of RF energy applied to the plasma. This value is measured in watts.

Impedance Matching: The matching of the fixed output impedance of the RF Power Generator to the constantly varying input impedance characteristic of a plasma. This is done to attain maximum transfer of available RF energy to the plasma and keep the plasma uniform.

Isotropic: Etching that is not directional in it's effect. Characteristic of most cleaning applications where it is desirable to remove material from all surfaces. Typical of barrel type etchers.



Matching Network: The module in the plasma system that accomplishes the matching of the fixed output impedance of the RF Power Generator to the constantly varying input impedance characteristic of a plasma.

Parameter: A variable in the plasma process that can be changed by the operator. A value chosen for the specific parameter is passed to a controlling device in the plasma system which will then regulate the plasma generation process accordingly. For example, RF Power Level is a parameter; a typical value assigned to this parameter would be 100 watts.

Plasma: A highly energetic state of matter produced when a gas is introduced into a chamber at low pressure and is excited by the application of RF energy. This results in a disassociation of the gas molecules into ions, free radicals and other reactive species which interact physically and chemically with exposed surfaces of materials.

Process: The plasma cycle. The complete sequence of steps a material is subjected to in order to attain desired results. A process can consist of single or multiple steps.

Process Recipe: A sequential listing of the total set of conditions which make up a process. This includes gas type and process parameters as well as sample loading and positioning in the treatment chamber.

Process Threshold Pressure: The pressure at which the plasma process is started. The lower the Process Threshold Pressure level, the less impurities will be present in the chamber when the process gas is introduced. By evacuating the chamber for a longer or shorter period of time at the commencement of the process cycle, more or less of the room air and water vapor present in the chamber will be pumped out before the process gas is introduced. Also referred to as **Base Pressure**.

Pump-down Speed: The amount of time required to reach Base (Threshold) Pressure once the chamber is placed under vacuum.

Radio Frequency(RF): The frequency range of the power generators used to create the plasma in the Plasmod equipment. The specific frequency is 13.56 MHz.

Reactive Ion Etching(RIE): A high energy plasma process. Due to high energy ion bombardment, material to be etched can be removed quickly.

Read point: Actual value of a parameter at any given time as monitored by that parameter control device's sensors and reported for the operator's information on the appropriate panel display.

Reflected Power: The amount of RF energy that is not successfully transferred to the plasma, due to an impedance mismatch. May also be referred to as **Reverse Power**.

Reverse Power: The amount of RF energy that is not successfully transferred to the plasma, due to an impedance mismatch. May also be referred to as **Reflected Power**.

Selectivity: Different materials have different etch rates when exposed to the same plasma. This phenomenon can be manipulated to control, through process parameter selection, the etch rate of separate components of a multiple substance device to preserve one material while removing another.

Set point: The value of a parameter entered into one of the system's control devices. Once set, the control device will keep the parameter at the set point throughout the course of the process.

Threshold Pressure: The pressure at which the plasma process begins. The lower the Process Threshold Pressure level, the less impurities will be present in the chamber when the process gas is introduced. By evacuating the chamber for a longer or shorter period of time at the commencement of the process cycle, more or less of the room air and water vapor present in the chamber will be pumped out before the process gas is introduced. Also referred to as **Base Pressure**.

Tuning: The process of controlling the settings of the tuning network components to effect best possible impedance matching. This can be performed through manual input from the operator or through an automatic function, whereby forward and reverse power levels are compared and a feedback is generated from that comparison which is used to set the value of the variable components.

Tuning network: A coupling network by which impedance matching is controlled and optimized by varying the phase and amplitude of the RF waves entering the treatment chamber. Alteration of these values compensates for any mismatch in impedance as the network couples the RF power to the chamber.

Ultimate Pressure: The minimum chamber vacuum level achievable, as indicated by observation of the chamber pressure after it has been subjected to vacuum for a period of time sufficient for the pressure reading to completely stabilize. The capacity of the vacuum pump, the dimensions of the connecting line between the vacuum pump and the chamber, and the overall vacuum integrity of these components all affect the achievable Ultimate Pressure.

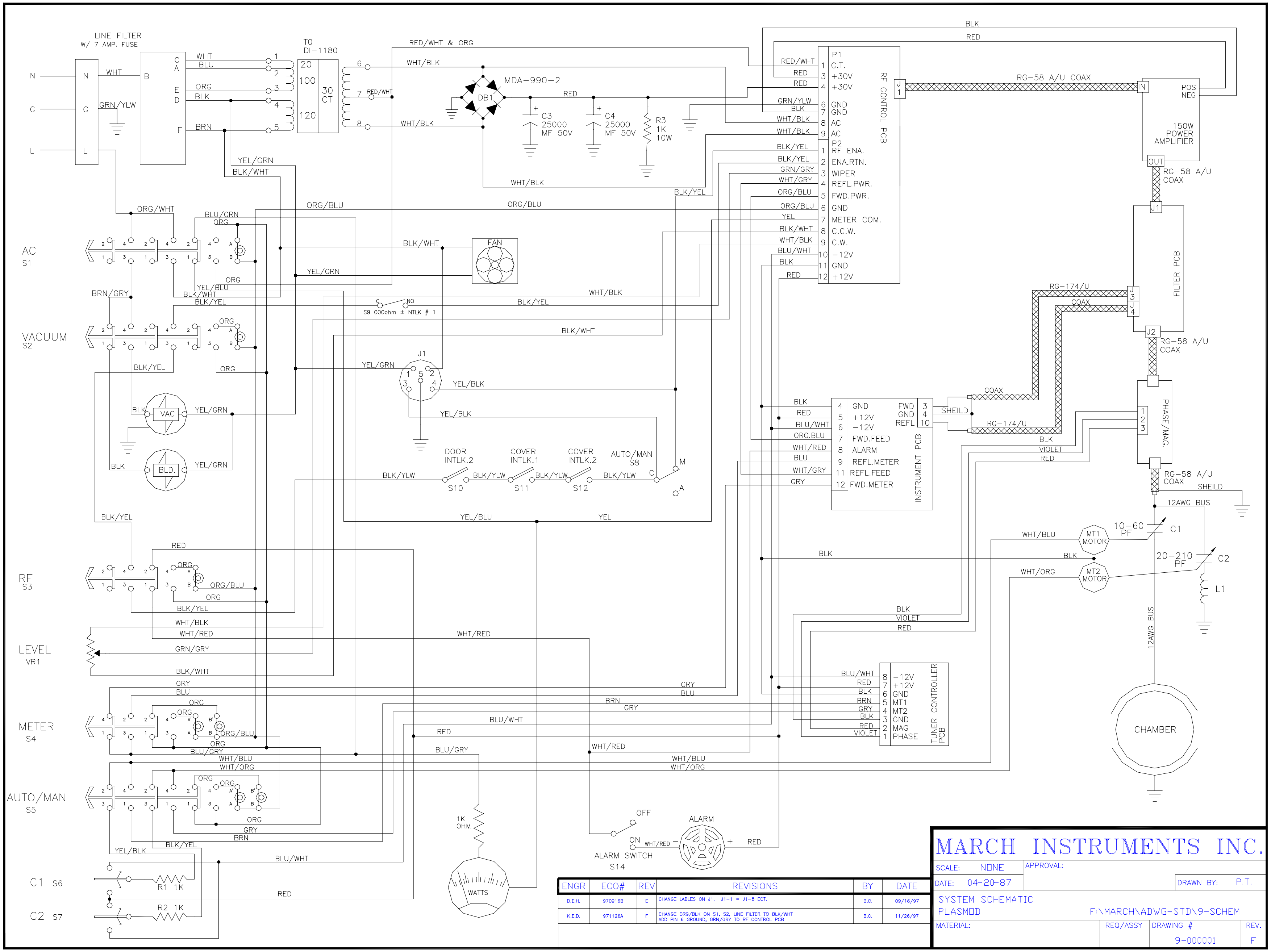
Ultraviolet (UV) Light: The region of the electromagnetic spectrum just beyond the visible wavelengths. The plasma environment is rich in UV light and this is one of the elements contributing to the surface modifications created by plasma.

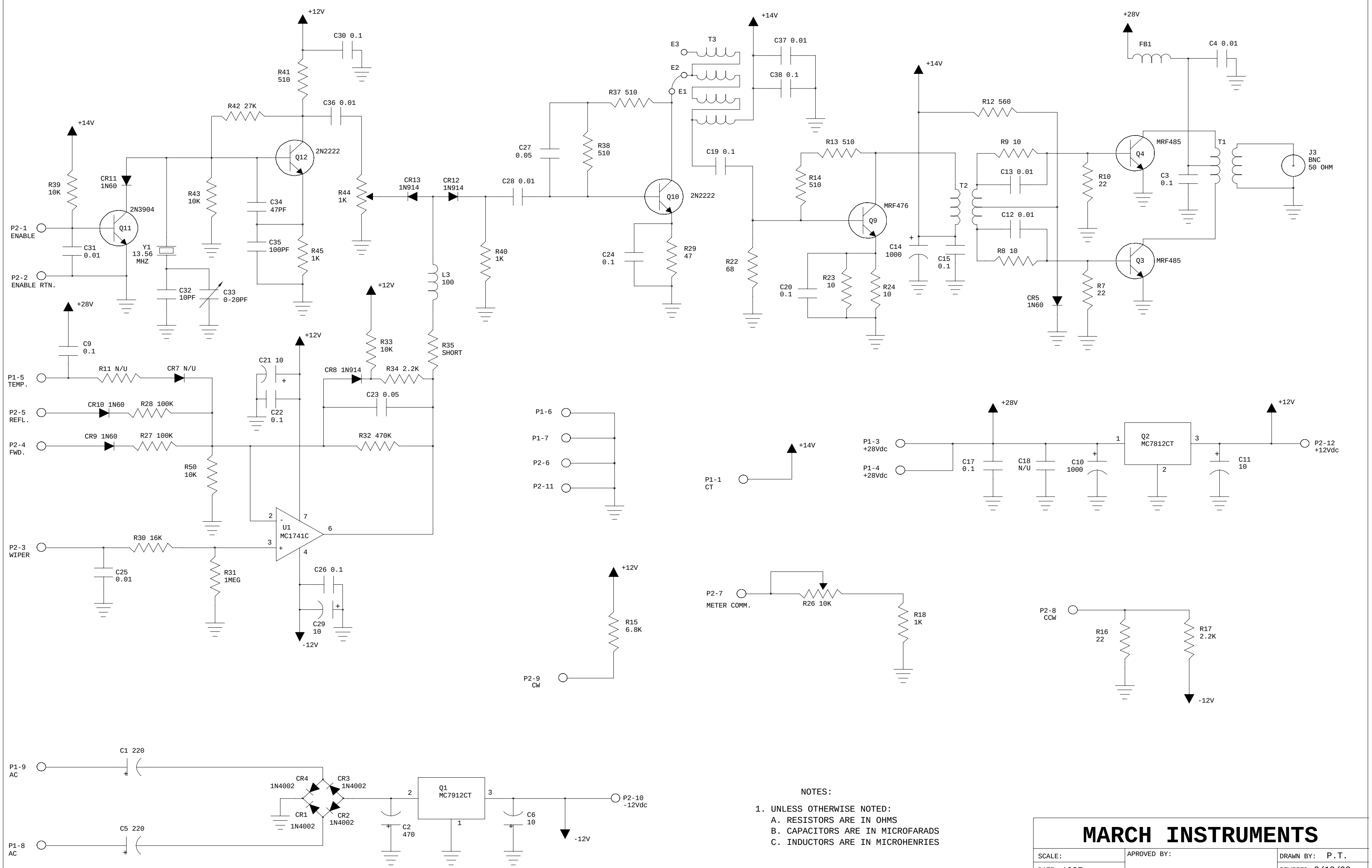
Uniformity: The degree to which the plasma process gives a uniform treatment across a materials surface. Also can refer to the degree plasma uniformity inside the chamber.

NOTES

SCHEMATICS

The following pages are the schematics for components of the Plasmod system. Included are schematics for the Tuning Controller PCB, RF Control PCB, Power Amplifier PCB, Phase/Mag PCB, Instrument PCB, Filter PCB, and the overall System schematic.


LINE FILTER W/ 7 AMP. FUSE
N
G
L
TO DI-1180
MDA-990-2
DB1
C3 25000 MF 50V
C4 25000 MF 50V
R3 1K 10W
RF CONTROL PCB
P1
1 C.T.
3 +30V
4 +30V
6 GND
7 GND
8 AC
9 AC
P2
1 RF ENA.
2 ENA.RTN.
3 WIPER
4 REFL.PWR.
5 FWD.PWR.
6 GND
7 METER COM.
8 C.C.W.
9 C.W.
10 -12V
11 GND
12 +12V
RG-58 A/U COAX
POS
NEG
150W POWER AMPLIFIER
OUT
RG-58 A/U COAX
FILTER PCB
RG-174/U COAX
RG-58 A/U COAX
PHASE/MAG.
AC S1
VACUUM S2
RF S3
LEVEL VR1
METER S4
AUTO/MAN S5
C1 S6
C2 S7
FAN
VAC
BLD.
S9 000ohm ± NTLK # 1
J1
DOOR INTLK.2 S10
COVER INTLK.1 S11
COVER INTLK.2 S12
AUTO/MAN S8
INSTRUMENT PCB
1 GND
5 +12V
6 -12V
7 FWD.FEED
8 ALARM
9 REFL.METER
11 REFL.FEED
12 FWD.METER
FWD
GND
REFL
SHEILD
MT1 MOTOR
MT2 MOTOR
10-60 PF C1
20-210 PF C2
L1
12AWG BUS
CHAMBER
TUNER CONTROLLER PCB
8 -12V
7 +12V
6 GND
5 MT1
4 MT2
3 GND
2 MAG
1 PHASE
R1 1K
R2 1K
1K OHM
WATTS
ALARM
OFF
ON
ALARM SWITCH S14
ENGR ECO# REV REVISIONS BY DATE
D.E.H. 970916B E CHANGE LABLES ON J1. J1-1 = J1-8 ECT. B.C. 09/16/97
K.E.D. 971126A F CHANGE ORG/BLK ON S1, S2, LINE FILTER TO BLK/WHT ADD PIN 6 GROUND, GRN/GRY TO RF CONTROL PCB B.C. 11/26/97
MARCH INSTRUMENTS INC.
SCALE: NONE
APPROVAL:
DATE: 04-20-87
DRAWN BY: P.T.
SYSTEM SCHEMATIC
PLASMOD
F:\MARCH\ADWG-STD\9-SCHEM
MATERIAL:
REQ/ASSY
DRAWING # 9-000001
REV. F



NOTES:

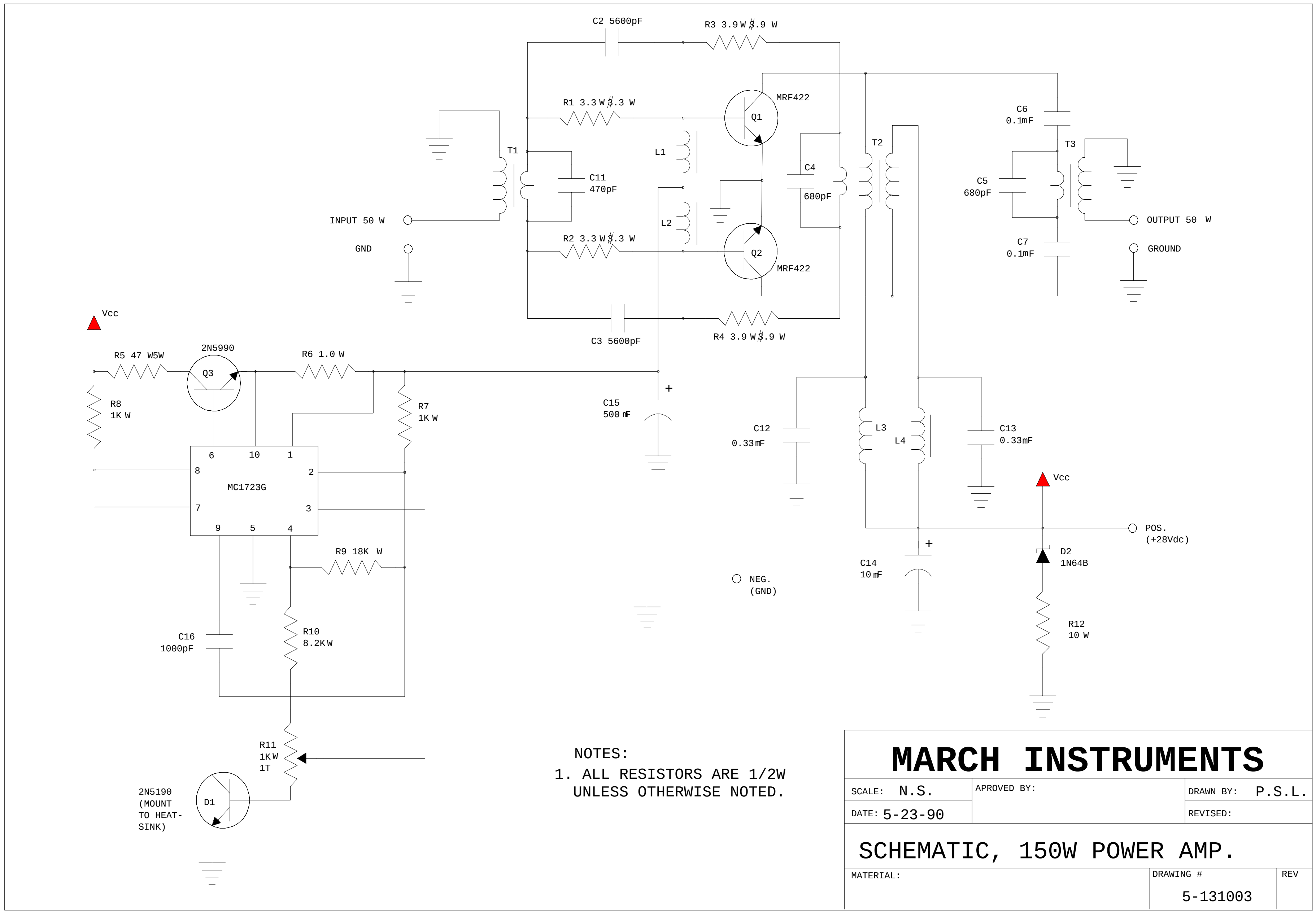
1. UNLESS OTHERWISE NOTED:
   A. RESISTORS ARE IN OHMS
   B. CAPACITORS ARE IN MICROFARADS
   C. INDUCTORS ARE IN MICROHENRIES

MARCH INSTRUMENTS

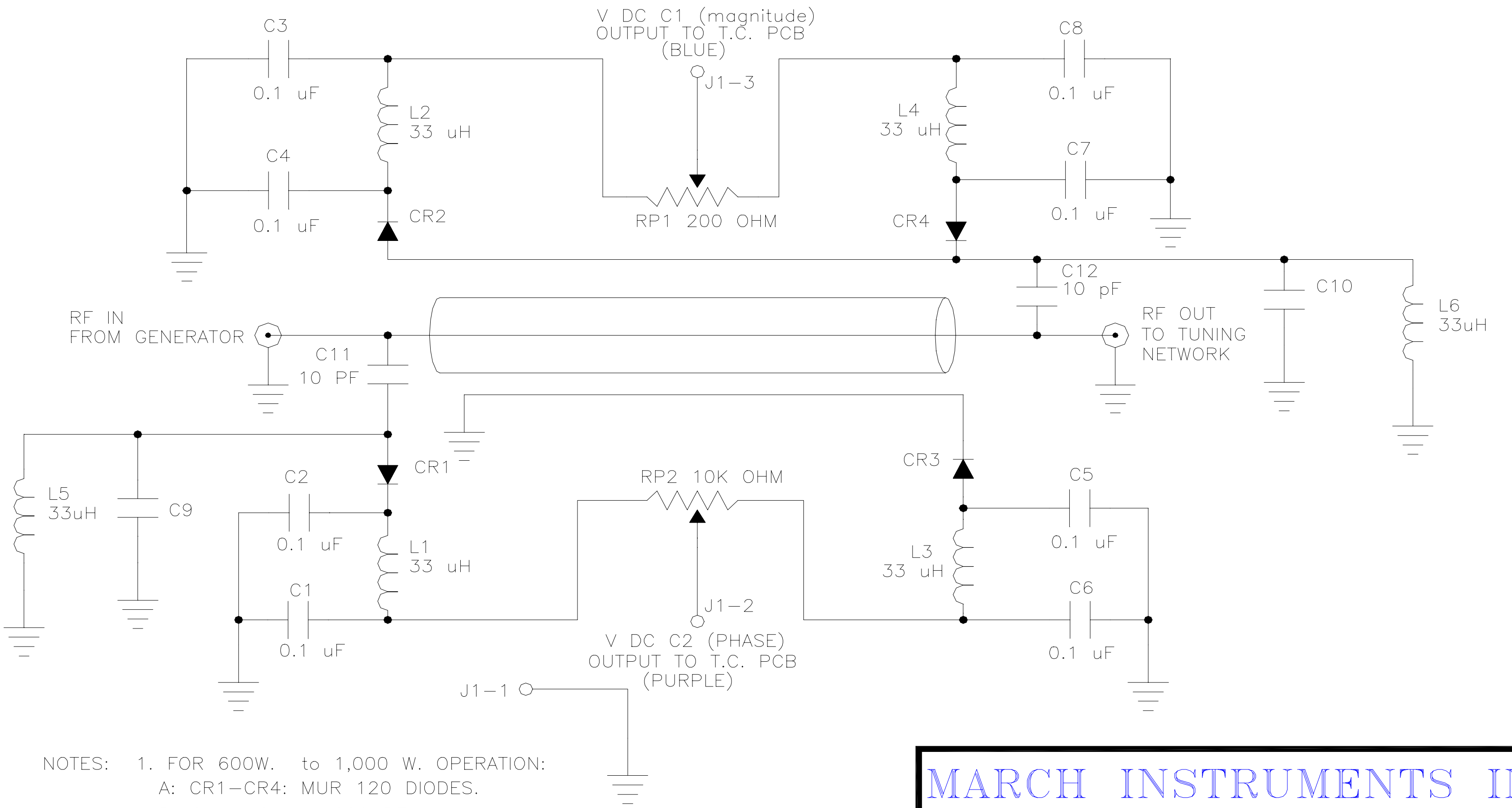
SCALE:	APROVED BY:	DRAWN BY: P.T.
DATE: 1987		REVISED: 3/18/93

SCHEMATIC, RF CONTROL PCB

MATERIAL:	DRAWING #	REV
	5-005001A	B


C2 5600pF
R3 3.9 W 3.9 W
R1 3.3 W 3.3 W
MRF422
Q1
T1
L1
C6
0.1mF
T2
T3
C11
470pF
C4
680pF
C5
680pF
INPUT 50 W
OUTPUT 50 W
L2
C7
0.1mF
GND
GROUND
R2 3.3 W 3.3 W
Q2
MRF422
C3 5600pF
R4 3.9 W 3.9 W
Vcc
R5 47 W5W
2N5990
Q3
R6 1.0 W
R8
1K W
R7
1K W
C15
500 mF
C12
0.33mF
L3
L4
C13
0.33mF
6
10
1
8
2
MC1723G
7
3
9
5
4
Vcc
POS.
(+28Vdc)
D2
1N64B
R9 18K W
C14
10 mF
NEG.
(GND)
C16
1000pF
R10
8.2K W
R12
10 W
R11
1K W
1T
2N5190
(MOUNT
TO HEAT-
SINK)
D1
NOTES:
1. ALL RESISTORS ARE 1/2W
UNLESS OTHERWISE NOTED.
MARCH INSTRUMENTS
SCALE: N.S.
APROVED BY:
DRAWN BY: P.S.L.
DATE: 5-23-90
REVISED:
SCHEMATIC, 150W POWER AMP.
MATERIAL:
DRAWING #
5-131003
REV

ENGR	ECO#	REV	REVISIONS	BY	DATE
D.E.H.	970520A	A	SHCEMATIC UPDATE	K.H.K.	7/15/97



NOTES:
1. FOR 600W. to 1,000 W. OPERATION:
   A: CR1-CR4: MUR 120 DIODES.
   B. C9 & C10: 1,000 PF .
2. FOR 300 TO 600 WATT
   A: CR1-CR4: 1N60
   B. C9 & C10: 680 pf
3. FOR PLASMODS (125W)
   A: CR1-CR4: 1N60
   B. C9 & C10: 470 pf

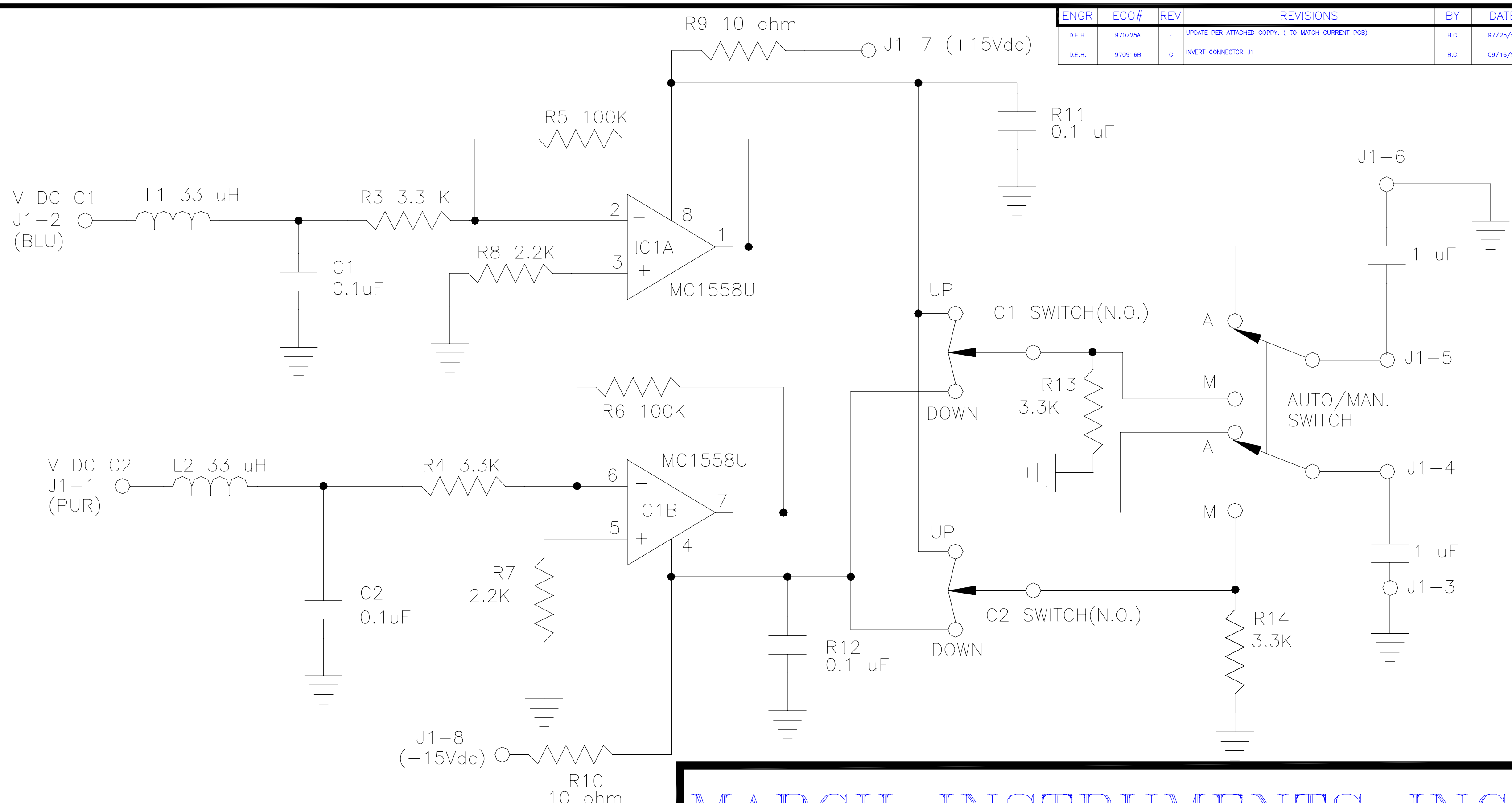
MARCH INSTRUMENTS INC.

SCALE: NONE	APPROVAL:	
DATE: 04-12-89		DRAWN BY: D.E.H.

PHASE/MAG P.C.B. SCHEMATIC
ALL F:\MARCH\ADWG-STD\5-PCB

MATERIAL:	REQ/ASSY	DRAWING #	REV.
		5-050011	E

ENGR	ECO#	REV	REVISIONS	BY	DATE
D.E.H.	970725A	F	UPDATE PER ATTACHED COPPY. (TO MATCH CURRENT PCB)	B.C.	97/25/97
D.E.H.	970916B	G	INVERT CONNECTOR J1	B.C.	09/16/97



NOTE: 1. WHEN ASSEMBLING, THE WORD "AMP" ON J1'S BODY MUST BE OUTBOARD ON THE PCB.

MARCH INSTRUMENTS INC.®

SCALE: NONE

APPROVAL:

DATE: 04-12-89

DRAWN BY: D.E.H.

TUNING CONTROLLER PCB SCHEMATIC

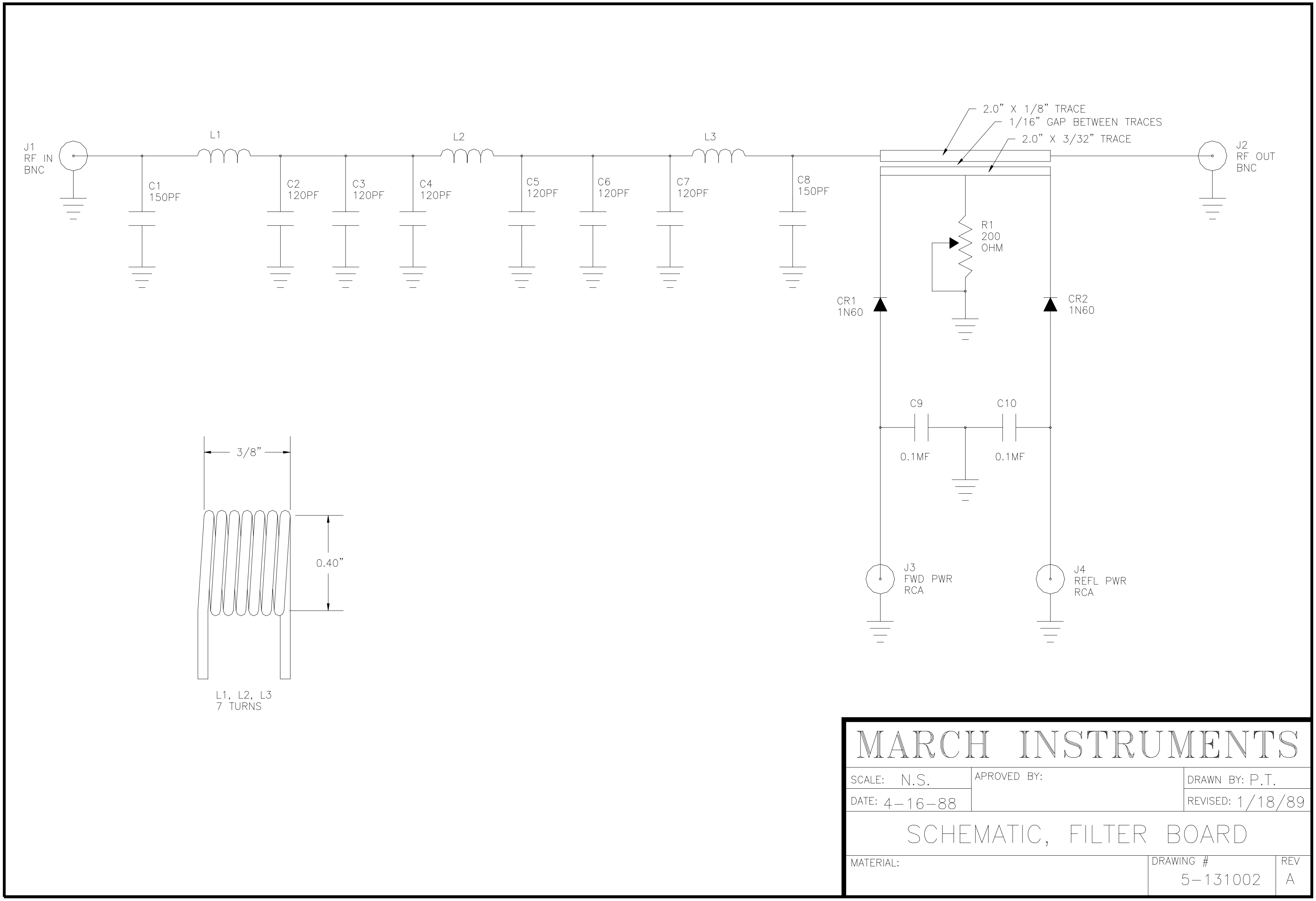
F:\MARCH\ADWG-STD\5-PCB

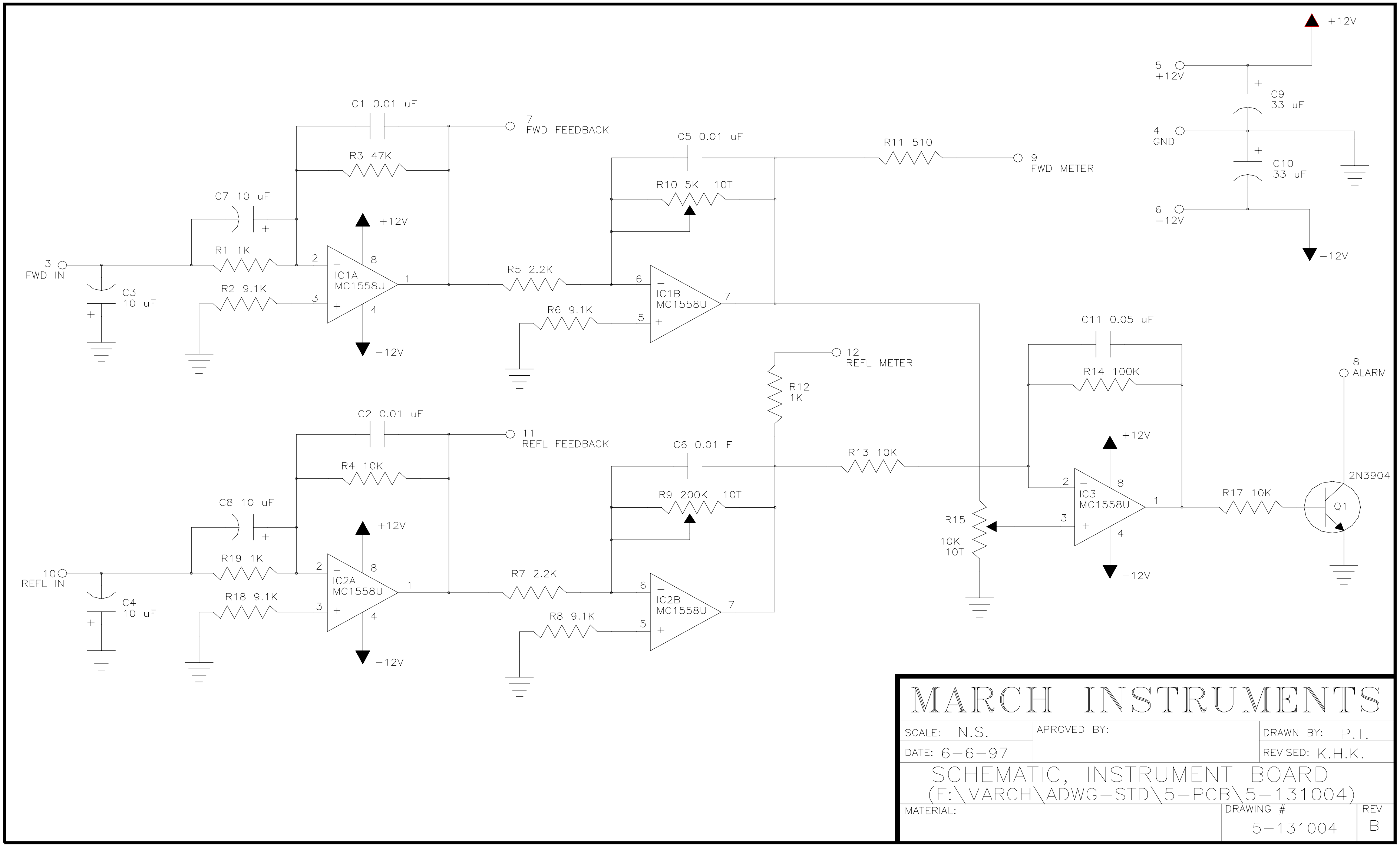
MATERIAL:

REQ/ASSY

DRAWING # 5-050010

REV. G


J1
RF IN
BNC
L1
L2
L3
C1
150PF
C2
120PF
C3
120PF
C4
120PF
C5
120PF
C6
120PF
C7
120PF
C8
150PF
2.0" X 1/8" TRACE
1/16" GAP BETWEEN TRACES
2.0" X 3/32" TRACE
J2
RF OUT
BNC
R1
200
OHM
CR1
1N60
CR2
1N60
C9
C10
0.1MF
0.1MF
J3
FWD PWR
RCA
J4
REFL PWR
RCA
3/8"
0.40"
L1, L2, L3
7 TURNS
MARCH INSTRUMENTS
SCALE: N.S.
APROVED BY:
DRAWN BY: P.T.
DATE: 4-16-88
REVISED: 1/18/89
SCHEMATIC, FILTER BOARD
MATERIAL:
DRAWING #
5-131002
REV
A


C1 0.01 uF
7
FWD FEEDBACK
R3 47K
C7 10 uF
R1 1K
R2 9.1K
3
FWD IN
C3
10 uF
IC1A
MC1558U
+12V
-12V
C5 0.01 uF
R10 5K 10T
R5 2.2K
R6 9.1K
IC1B
MC1558U
R11 510
9
FWD METER
5
+12V
4
GND
6
-12V
C9
33 uF
C10
33 uF
+12V
-12V
C11 0.05 uF
R14 100K
12
REFL METER
R12
1K
8
ALARM
C2 0.01 uF
11
REFL FEEDBACK
R4 10K
C8 10 uF
R19 1K
R18 9.1K
10
REFL IN
C4
10 uF
IC2A
MC1558U
C6 0.01 F
R9 200K 10T
R13 10K
R7 2.2K
R8 9.1K
IC2B
MC1558U
R15
10K
10T
IC3
MC1558U
R17 10K
2N3904
Q1
MARCH INSTRUMENTS
SCALE: N.S.
APROVED BY:
DRAWN BY: P.T.
DATE: 6-6-97
REVISED: K.H.K.
SCHEMATIC, INSTRUMENT BOARD
(F:\MARCH\ADWG-STD\5-PCB\5-131004)
MATERIAL:
DRAWING #
5-131004
REV
B