MANITOU SYSTEMS INC

High-powered solutions for RF and microwave applications

***PROCESS OPTIMIZED RF POWER SYSTEMS AND COMPONENTS***

# *MODEL MTK-600*

# *RF MANUAL IMPEDANCE MATCHING SYSTEM*

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## *OWNERS MANUAL*


CUSTOMER ______________________________________________

DATE ___________________________________________________

SERIAL #      CONTROLLER_____________________________

TUNER__________________________________

ACCESSORY______________________________

ACCESSORY______________________________

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 MTK-600 Part # 03-700000-01-M

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***WARNING*** Lethal RF and DC voltages are present in this system.
**Only qualified** personnel should install and service this equipment.

Prior to installation and operation of this system, this instruction manual should be consulted to ensure that the installation and operation are in accordance with **Manitou Systems**' recommendations.

Failure to properly install or operate this unit will result in voiding the equipment warranty.



This owner's manual is provided to enable the user to safely install, operate and service the equipment described.

Manitou Systems, Inc. reserves the right to make product changes and enhancements without notification or obligation.

For more information, please write Manitou Systems, Inc., 12 South Street, Danbury, CT 06810 USA or contact us via Telephone at (203) 792-8797, FAX at (203) 792-7097 or E-mail at info@manitousys.com.

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## 1.1 GENERAL DESCRIPTION

The budget minded **MTK-600** is specifically designed for continuous operation in gas plasma process applications.

The manual RF impedance matching network is housed in a single, compact enclosure, and provides the user with a broad tuning range. The network includes a series inductor with a field changeable tap (interchangeable inductors on VHF units) and optional additional fixed shunt capacitors, enabling it to match a wide range of plasma electrode impedances.

## 1.2 MATCHING NETWORK SPECIFICATIONS

| | |
|---|---|
| Maximum RF Power: | 600 W |
| Operating Frequency: | 13.56 MHz (Standard.) (13-125 MHz versions available) |
| RF Output Connector: | Type "HN" female coaxial cable connector |
| RF Input Connector: | Type "N" female coaxial cable connector |
| RF Input Impedance: | 50 Ω |
| Circuit Topology: | "L" using a variable shunt capacitor and a tapped series inductor & variable capacitor. Additional fixed shunt capacitors may be added to match low impedance loads. |
| Cooling: | Forced air, max ambient temp 40° C (104° F) |
| Dimensions: | 9x6x6” (~23x16x16cm) (LxWxH) |
| Weight: | 5 lbs. (2.27 kg) |
| Output Impedance: | Wide range - will match to all sputtering sources and plasma etching / deposition electrodes. |
| Power Requirement: | 110 Vac, 50-60 Hz, 4 W |

## 1.3 MECHANICAL DESCRIPTION

The system consists of a manual matching network housed in an irridited aluminum cabinet, and a 110 Vac wall power pack to provide 24 Vdc to the network cooling fan.

The cabinet, including the tuning knobs and cooling fan, measures approximately 9” long x 6” wide by 6” high.

The cabinet incorporates 10-32 threaded mounting holes on its bottom and rear surfaces.

Cooling air is drawn in through the side of the cabinet, and is exhausted by a rear-mounted fan.

The capacitor position adjustment knobs are located on the front panel. The RF input & output connectors, and the cooling fan, are located on the rear of the cabinet.

## 1.4 SAFETY PRECAUTIONS

SAFE OPERATION IS THE RESPONSIBILITY OF THE USING ORGANIZATION AND ITS PERSONNEL. READ THIS OWNERS MANUAL AND UNDERSTAND HOW TO AVOID HAZARDS PRIOR TO OPERATING THIS UNIT.

Your compliance with the following safety practices is expected:

1. Never work alone on live electrical circuits. You must be within sight or calling distance of another employee who has the following qualifications:

   A. Knows how to remove power from the equipment.
   B. Knows how to perform artificial respiration.
   C. Is acquainted with emergency procedures, first aid locations and the use of fire extinguishers.

2. Do not wear rings, wristwatches or other jewelry while working on live electrical circuits.

3. Wear eye protection while working on live electrical circuitry where a flash might occur. **DO NOT WEAR CONTACT LENSES**.

### 1.4 SAFETY PRECAUTIONS cont.

4. Because currents of 40 mA or greater across the chest can be fatal, before working on the equipment read this manual to find out how much current is present in each circuit. **EXERCISE EXTREME CAUTION!**

5. Replace all covers and safety shields after completing any system setup, troubleshooting or maintenance procedures.

6. Immediately report any unsafe conditions to your supervisor.

***WARNING*** Proper use and safe operating practices with respect to this system are the responsibility of the user of the system. Manitou Systems, Inc. provides information on its products and their associated hazards, but it assumes no responsibility for after-sale operation and safety practices; take appropriate action to protect personnel and property from hardware failure. All personnel who work with or are exposed to this system must take precautions to protect themselves against possible serious and/or fatal bodily injury. **DO NOT** be careless around this system.

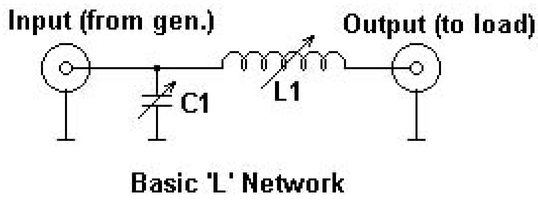
### 1.5 THEORY OF OPERATION

The manual impedance matching network utilizes an "L" circuit topology, so named because of the configuration of the elements used (see fig. 1, Basic ‘L’ Network). The basic ‘L’ type match network requires only two components, a variable shunt (parallel) capacitance (C1) and a variable series inductor (L1).

In actual practice, however (see fig. 1, Practical ‘L’ Network), a fixed inductor (L1) is typically used (it is difficult or impossible to obtain a variable inductor with a sliding contact capable of carrying the high RF currents that are present in a plasma application) with a variable capacitor (C2) connected in series with it. The variable capacitor is then used to tune *out* part of the series inductance, the net effect being the same as a tunable inductor but without the inherent current-carrying problems noted above. C1 performs the shunt function, as in the basic network.

These three elements are used to match the complex plasma impedance and present the RF generator with a 50 Ω resistive load. As delivered, this network exhibits a wide range output impedance and will match to most sputtering sources and plasma etching / deposition electrodes

Many matching networks (this one included) use a fixed inductor with several manually changeable taps to allow a greater range of load impedances to be matched. An additional fixed shunt capacitance may also be added if necessary to match loads with very low impedances.



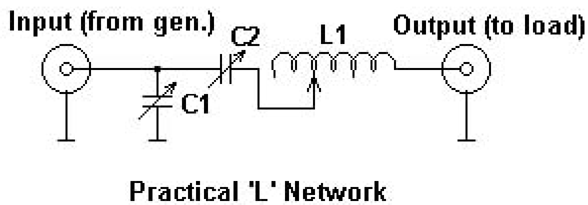




**Figure 1- Matching Network Configurations**

## 2.1 UNPACKING

Remove the unit from its shipping container. Examine it for any damage and contact **Manitou Systems** and the shipping carrier if any is noted.

## 2.2 SCOPE OF DELIVERY

MTK 600 Match Network
24 Vdc Wall Pack for cooling fan
Interchangeable inductor set (40-125MHz models only)

## 2.3 INSTALLATION

### 2.3.1 General Considerations

Proper installation and connection of the match network to the plasma load has a major influence on the satisfactory operation of an RF system. The real impedance of the plasma is typically very low (on the order of between 1 and 10Ω in many systems), resulting in very high levels of current flow in the connections and conductors between the matching network and the chamber. These high currents, along with the tendency of RF current to flow only on the surface of a conductor (skin effect) combine to cause power losses in the leads carrying the RF between the matching network and the plasma load.

In the interests of minimizing these losses, as well as reducing radio frequency radiation, the leads connecting the match network to the plasma load should be kept as short as possible, and the conductors should have as much surface area as possible.

### 2.3.2 Grounding

It is essential that the enclosure of the match network be properly bonded to the ground of the plasma system. Failure to ensure a good connection between the ground of the system and that of the match network may result in RF radiation and, more importantly, the possibility of electric shock from the match unit’s cabinet. (Current flowing through a poorly bonded ground connection can result in a potential difference between the cabinet of the match network and the chassis of the plasma system.)

It is suggested that the chassis of the match network be fixed directly to the chamber of the plasma system using the 10-32 mounting holes on the bottom or rear of the cabinet. If mounting the match network directly on the chamber is impractical, a ground connection strap at least 1” wide should be connected as directly as possible between the network and the system ground.

### 2.3.3 RF Output Connection

The output of the match network is equipped with a female HN connector. This should be connected to the sputter or plasma electrode using a teflon based coaxial cable, keeping the length of the cable as short as possible. A teflon insulated cable is preferred for this connection, as the cable tends to become hot due to the high current flow and heat transferred by conduction from the plasma itself.

### 2.3.4 Mounting the Network

The matching network is mounted using 10-32 screws threaded into the bottom or rear plate. It may be fastened directly to the frame of the plasma system using these mounting holes, or it may be attached to a bracket that is then mounted on the plasma system. As mentioned in section 2.3.2, ensure that there is a good ground connection between the match network and the system ground.

### 2.3.5 Mounting the Network

An example of system configuration is shown in figure 2 below.

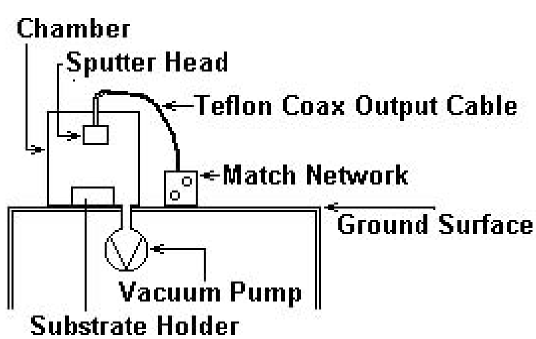



**Figure 2- Connection of Network to Sputter Head**

## 3.1 CONTROLS AND CONNECTIONS


**Figure 3- MTK Front Panel**

**Figure 4- MTK Rear Panel**

The front panel of the matching network holds the vernier controls for the variable capacitors used for tuning. (see fig. 3 above)

The rear panel holds the RF input (type ‘N’) and output (type ‘HN’) connectors, and the cooling fan. (see fig. 4 above)

## 3.2 PRELIMINARY CONTROL SETTINGS

Preset the tune and load capacitors to a known plasma ignition point. If the plasma ignition point is unknown, preset the capacitors to 50%.

## 3.3 TURNING ON THE RF POWER

Turn the RF on. Adjust the RF power level to an amount sufficient to initiate a plasma discharge in the chamber.

## 3.4 TUNING THE MATCH NETWORK

Adjust the TUNE capacitor throughout its range while observing the forward and reflected power on the RF generator, and checking for the initiation of a plasma discharge in the chamber. At some point in the TUNE capacitor's travel, a sharp peak in the forward power should be observed (this assumes that the generator is in reflected power foldback- if it is not, then indicated forward power may not change at all), coinciding with a drop in the reflected power and the initiation of the plasma discharge. If the preceding events do not occur, adjust the LOAD capacitor position slightly and repeat the process.

After the plasma has ignited, slowly adjust the LOAD capacitor for minimum reflected power. If there is still reflected power present even at the LOAD capacitor's best tune point, switch back to the TUNE capacitor and adjust it for the lowest reflected power possible. Several iterations of alternately adjusting the TUNE and LOAD capacitors may be needed to achieve minimum reflected power. The tune points of the capacitors should be noted for future reference.

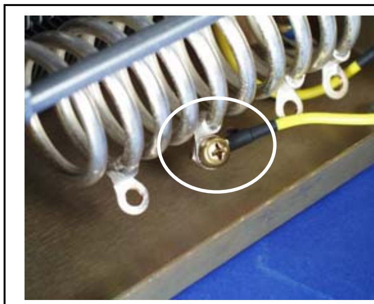
## 3.5 ADJUSTING THE SERIES INDUCTANCE (Tapped coil unit)

The low frequency (13-40 MHz) versions of the matching network utilize a tapped coil for the series Inductor.

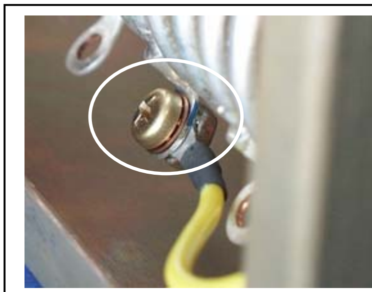
MTK 600 w/ tapped inductor

***WARNING*—MAKE ALL INDUCTANCE ADJUSTMENTS WITH THE RF POWER TURNED OFF AND THE RF INPUT CABLE DISCONNECTED FROM THE NETWORK**

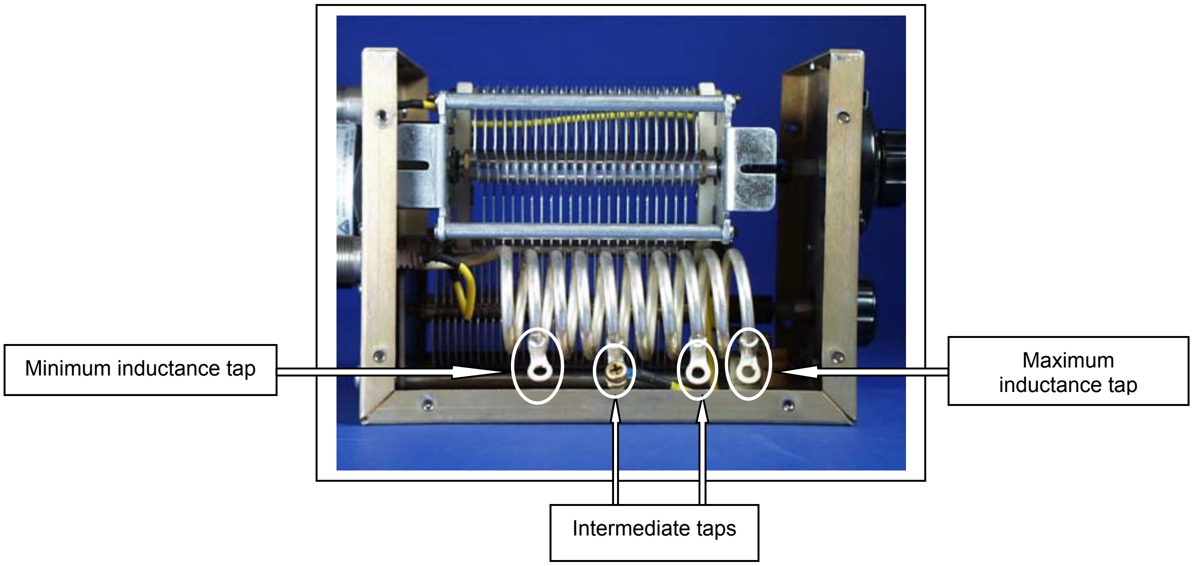
The inductance of the coil is varied by changing the tap to which the yellow Teflon wire coming from the series capacitor is connected. To increase the inductance, move the wire to a tap closer to the front of the match network (more coil in the circuit between the tap and the output connector), to decrease the inductance, move the wire to a tap closer to the rear of the network.



Inductor tap connection (typ)



Inductor tap connection detail

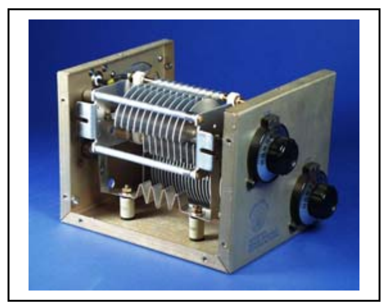



Inductor tap locations

### 3.6 ADJUSTING THE SERIES INDUCTANCE (Interchangeable strip inductor unit)

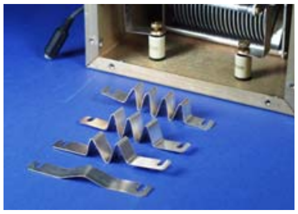
The VHF (40-125MHz) versions of the match network, needing much less inductance than the low frequency models, do not use tapped coils; instead they are supplied with several strip inductors of various lengths.

***WARNING*—MAKE ALL INDUCTANCE ADJUSTMENTS WITH THE RF POWER TURNED OFF AND THE RF INPUT CABLE DISCONNECTED FROM THE NETWORK**

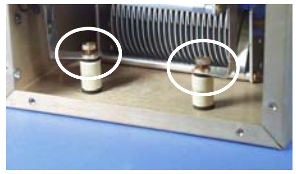


MTK 600 w/ strip inductor

To change the series inductance, the entire inductor is removed from the network and replaced with a longer or shorter one (more or less inductance, respectively) as needed. The inductor is mounted between two ceramic standoffs mounted on the bottom of the match network, as shown in the photos below. To change the inductor, loosen the brass nuts that hold it in place and slide it out towards the side of the match network (the mounting points of the inductors are slotted so they may be slipped into place). Install the replacement inductor by sliding it in between the two brass flat washers on the mounting stud, then tighten the nuts. ***CAUTION***- do not over tighten the nuts. The studs are screwed into ceramic standoffs and the standoffs may crack if the nuts are tightened excessively.

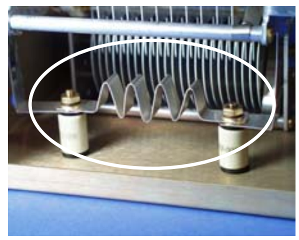


HF inductor set

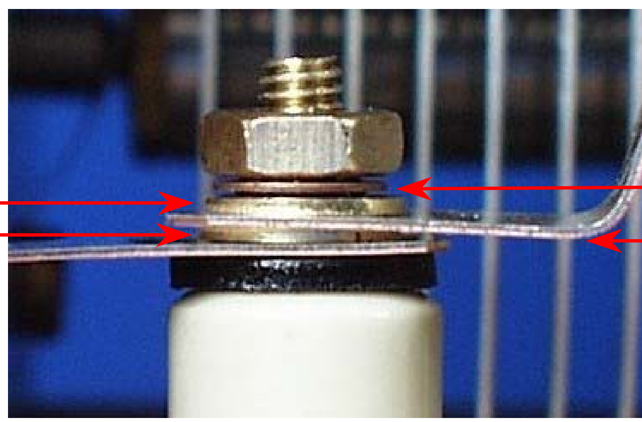


Inductor mounting location

Slot detail



Installed inductor (typical)




Inductor connection detail
(Output side shown, input similar)

## 3.7 OPTIMIZING THE MATCH NETWORK FOR OPERATION WITH A GIVEN LOAD

As a general rule, a small electrode typically requires greater series inductance than a large one. 1 to 1-1/2" sputter guns will probably tune best with the movable tap positioned towards the front of the match network (high inductance), while 2 to 3" ones will operate with the tap connected more to the middle to low inductance range.

Further determination of the correct series inductance value can be achieved once plasma ignition has been established by noting the position of the series (TUNE) capacitor when the network has been adjusted to achieve the minimum reflected power. Ideally, when the load is tuned the tune capacitor should be positioned somewhere between 15-20% and 75-80% of its adjustment range, the closer to the middle the better. This will allow the widest variation in load conditions to be tuned without the need to further adjust the inductor.

To optimize the inductor setting, turn on the RF and establish a plasma under normal operating conditions if possible, if not then under conditions as close to those desired as possible with the network in its present state. Tune for minimum reflected power, and note the position of the TUNE (series) and LOAD (shunt) capacitors. The TUNE capacitor position will determine what to do with the series inductance, and the LOAD capacitor position will show if additional fixed shunt capacitance must be added.

If the minimum reflected power is obtained with the TUNE capacitor set towards the bottom of its range (minimum 'C', maximum $X_c$), this is an indication that the series inductor is too large (as mentioned previously in the 'theory of operation' section, the series capacitor's reactance, being 180° out of phase with the inductor's reactance, is used to cancel out some of the inductive reactance.) If this is the situation, move the tap on the inductor towards the rear of the match network (fewer turns), or in the case of the HF network with interchangeable inductors, install a smaller (shorter) one.

If minimum reflected power is obtained with the TUNE capacitor adjusted towards the top of its range (maximum 'C', minimum $X_c$), this indicates that the series inductor is too small. If this is the case, the tap on the inductor should be moved towards the front of the network (more turns), or, in the HF network, a larger (longer) inductor should be installed. (In rare cases, it may be necessary to install additional series inductance- should this possibility arise, contact Manitou Systems for further information.)

Systems with large electrodes, the use of long cables running between the match network and load (longer than perhaps 4' or so), or parallel output cables (used with some manufacturer's sputter guns) *may* necessitate the installation of additional fixed shunt capacitance in the network. To determine if additional shunt capacitance is required, note the position of the LOAD (shunt) capacitor when the system is adjusted for minimum reflected power. If the LOAD capacitor is adjusted to a position greater than 80-90%, additional fixed shunt C is likely required. Contact Manitou Systems for further information; a fixed shunt capacitor kit is available for the MTK.

## 4.1 PLASMA WILL NOT IGNITE

- RF Power setpoint not high enough to start plasma.
- RF Cables improperly connected or connections loose.
- Chamber pressure too low for ignition. Temporarily increase chamber pressure for ignition period only.
- Preset positions of LOAD and/or TUNE capacitors incorrect.
- Problem with sputter head or plasma electrode. Shorted target? (See equipment manufacturer's instruction manual.)
- Type of process gas- electro negative gasses may be difficult to ignite.
- Position of tap on series inductor:

  A small electrode typically requires more series inductance- the tap should be positioned towards the end of the inductor furthest from the series capacitor (maximum inductance).

  A medium-sized electrode usually requires the tap to be positioned near the middle of the inductor.

  A large electrode requires a minimum of series inductance, and the tap should typically be attached near the end of the coil closest to the series capacitor.

## 4.2 INABILITY TO TUNE TO ZERO REFLECTED POWER

Sometimes despite the load being tuned properly, the generator will still indicate that there is reflected power present. This reflected power indication is caused by plasma-generated harmonics coming back from the load being picked up by the RF generator's power detector. At the fundamental generator frequency there will be little or no 'actual' reflected power, however, the harmonic energy will be present and picked up by the power detection circuitry and displayed as reflected power.

One possible cure for this condition is to change the length of the cable running between the generator's RF output and the match network input. The generator-to-match cable should typically be an odd multiple of ¼ wavelength ($\lambda$) of the generator's operating frequency (¼ $\lambda$, ¾ $\lambda$, 1-¼ $\lambda$, etc…). If reflected power indications due to harmonics are present, lengthening or shortening the cable by ~5% may improve things.

Another possible cure for this condition is to install a 50Ω low-pass filter in the RF line between the generator output and matching network input. The filter should pass the generator's fundamental frequency, but cut off those above it. For optimal effect, the filter should be installed at the match network input rather than at the generator's RF output.