PALM TECHNOLOGY, INC.

ENStat 3™

Anodic Passivation System

Model 3700

Operating Manual

Version 1.02

INSTALLATION AND OPERATING MANUAL

MODEL 3700 ENstat 3™ ANODIC PASSIVATION SYSTEM

TABLE OF CONTENTS

Section I
Introduction

ENstat 3 is electrochemical system for continuously passivating the stainless steel components used in electroless nickel plating baths. Its use helps prevent plate-out and avoids stripping the tank with nitric acid on a daily basis. This system also reduces the disposal of spent nitric acid solutions and the cost of their waste treatment.

The **ENstat 3** is based upon the electrochemical technique of anodic protection, which has been used for many years to prevent corrosion in the chemical industries. Anodic protection produces a passive film on the stainless steel by discharging a small impressed current from it at a carefully controlled potential. This film is very similar to that produced by nitric acid passivation and prevents deposition of electroless nickel, while also avoiding corrosion.

The difference between this technique and the reverse current method used in the past, is that with deplating the potential of the stainless steel is not controlled. Instead a large current is discharged from the metal to keep it from plating. This current, however, also causes the stainless steel to corrode and become etched, especially at welds. With **ENstat 3** only the amount of current needed to maintain the potential of the metal within a desired range and to prevent plate-out is discharged. In addition, at the proper potential, most current is discharged through oxygen evolution rather than by metal dissolution.

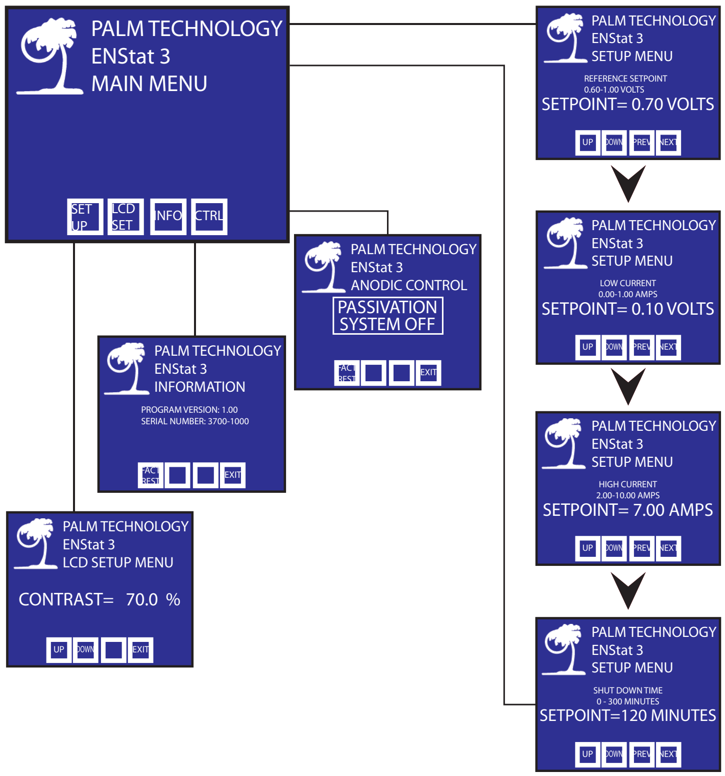
Not only will the **ENstat 3** protect the plating tank, but it will also reduce plate-out in the stainless steel pumps and heat exchangers electrically connected to it. Because protection is not dependent upon current flow, passivation does not change significantly with distance.

Hundreds of anodic protection systems have been installed on electroless nickel plating tanks in Europe, some for more than twenty-five years. These installations have been very successful and have allowed the plating solutions to remain in the same tank for as long as four months without nitric acid passivation.

Section II
The ENStat 3™ User Interface

The ENStat 3™ Model 3700 controller has a unique and easy to use interface. Its 4.5 inch wide LCD makes setting up and using the system as easy as possible All setup variables and alarms have user friendly informational screens to guide the user.

The ENStat 3™ Model 3700 starts up in the main menu, all user setup and control will begin from the main menu. The following shows the main menu and a flow diagram of the sub-screens.



Main Menu and sub screens

The operating manual will use the following format for guiding you on how to setup and enter data in the ENStat 3™ system.

1. Informational notes will have the  information symbol.

2. Warning information will have the  warning symbol.

3. Each **Step** for setting up unit will be numbered and in bold type

4. Menu navigation will be Centered, Bolded, Italisized and have **>** between button presses.

MAIN MENU > SETUP

Section III
Installing the System

The installation of the **ENstat 3** anodic protection controller and its components is illustrated by Figure 1 and is described by the following paragraphs.

STEP 1: Unpack all of the shipping containers and inspect the contents to ensure that no damage has occurred during shipment and that all of the components are present. The system will include at least the following components:

- **ENstat 3** controller enclosure,
- Reference electrode with its attached cable,
- Anode cable, and
- Operating manual.

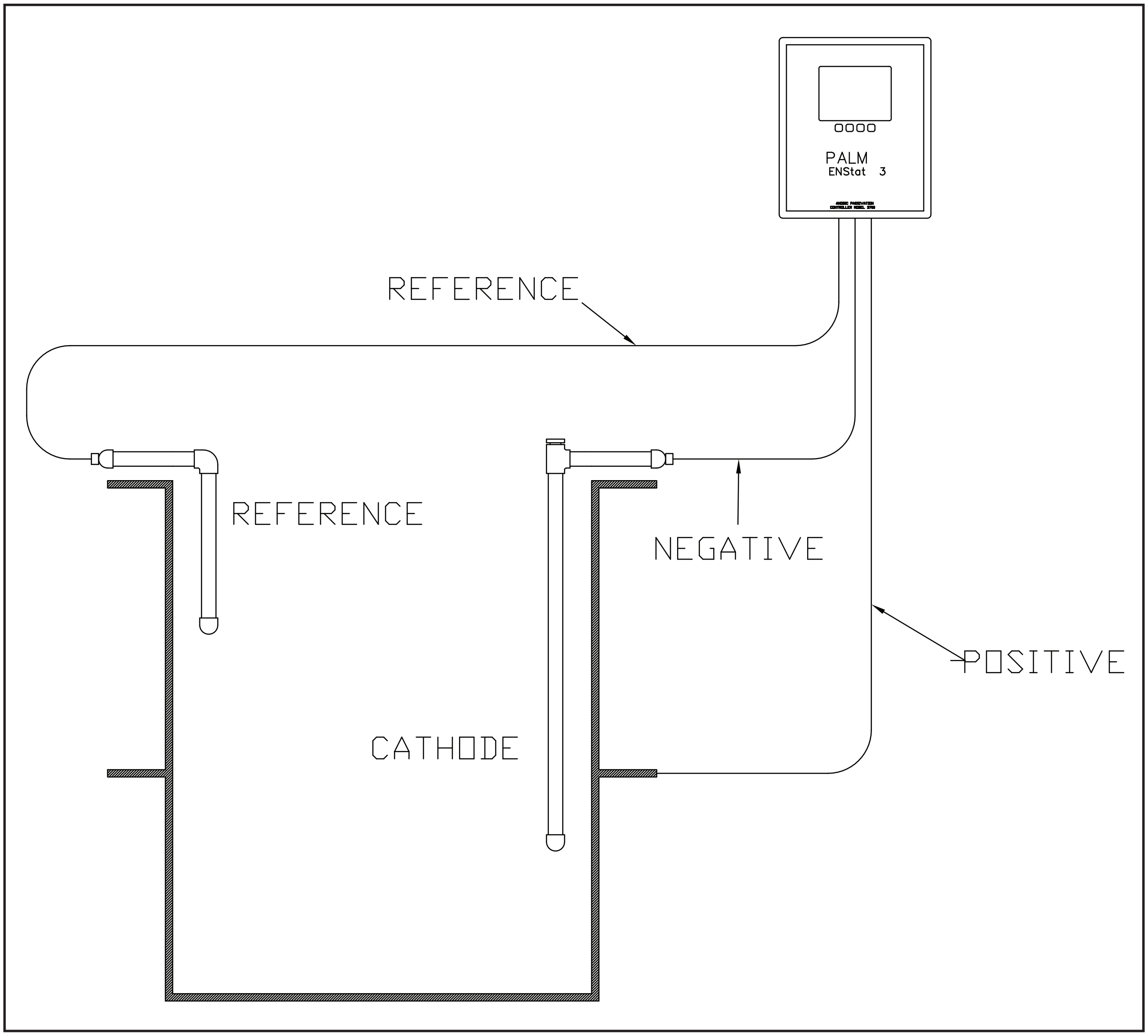
It may also include one or more cathodes with attached cables, a spare reference electrode, or a Model 2702 switch. The list of materials, enclosed with the shipment, shows its contents.

STEP 2: Mount the controller enclosure within fifteen feet (4.5 meters) of the plating tank. Locating the controller more than twenty-five feet from the plating tank will increase the voltage drop through the cables and may reduce the accuracy of the instrument.

The best location for the controller is on a nearby wall, away from traffic, steam, harmful vapors and potential damage. The enclosure has mounting lugs that can be used to attach it to a wall or other structure.

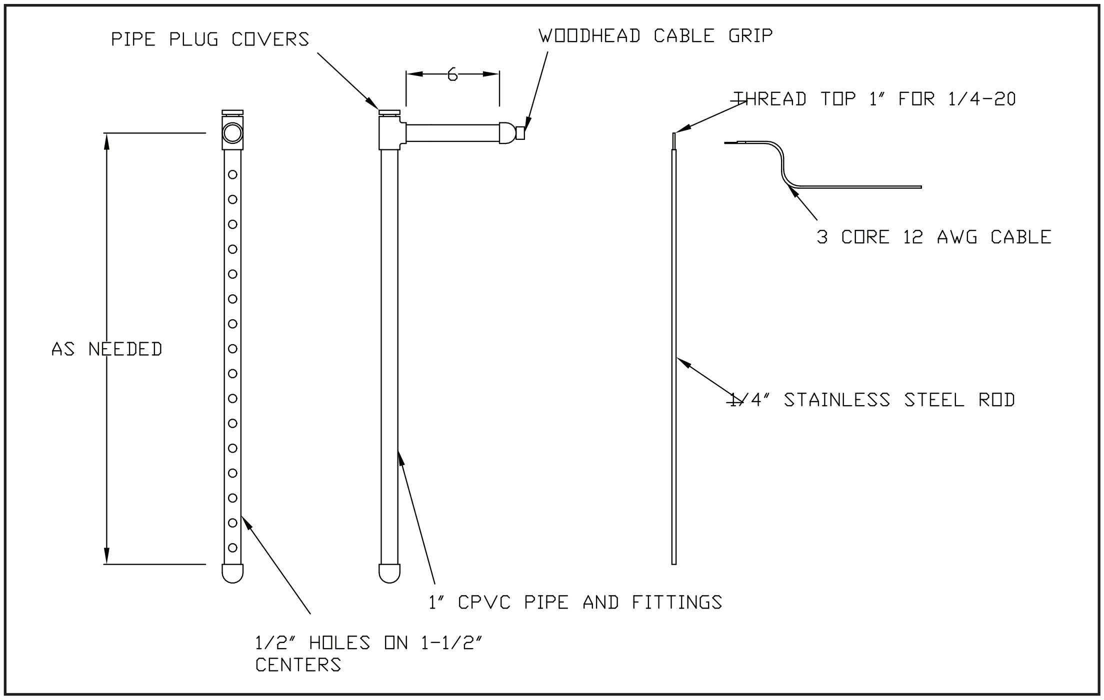
STEP 3: Install one or more cathodes and the reference electrode in the tank also as illustrated by Figure 1. They should be placed in a location where they will be protected from damage and will not interfere with the work being processed. Usually, this location is the corners of the tank. The design of a typical cathode is shown in Figure 2. The design of a standard reference electrode is shown in Figure 3.

Figure 1
Installing the ENStat 3



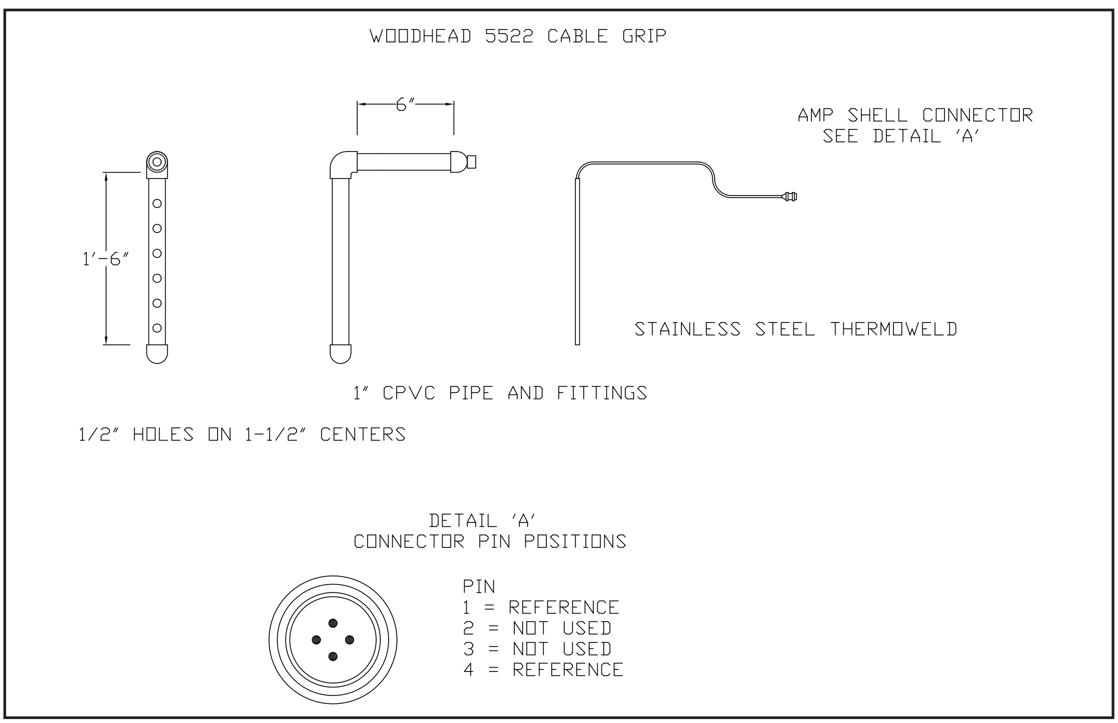
NOTE: With most installations stainless steel reference electrodes and cathodes are used. For the system to operate correctly, these electrodes must freely plate in the electroless nickel solution. This requirement usually means that the stainless steel components must be struck in a Woods or sulfamate nickel strike bath before they are placed in the electroless nickel tank. For those facilities that cannot strike stainless steel, plain steel cathodes and reference electrode is available. The design of this reference electrode is shown in **Figure 4.**

Figure 2
Typical Cathode



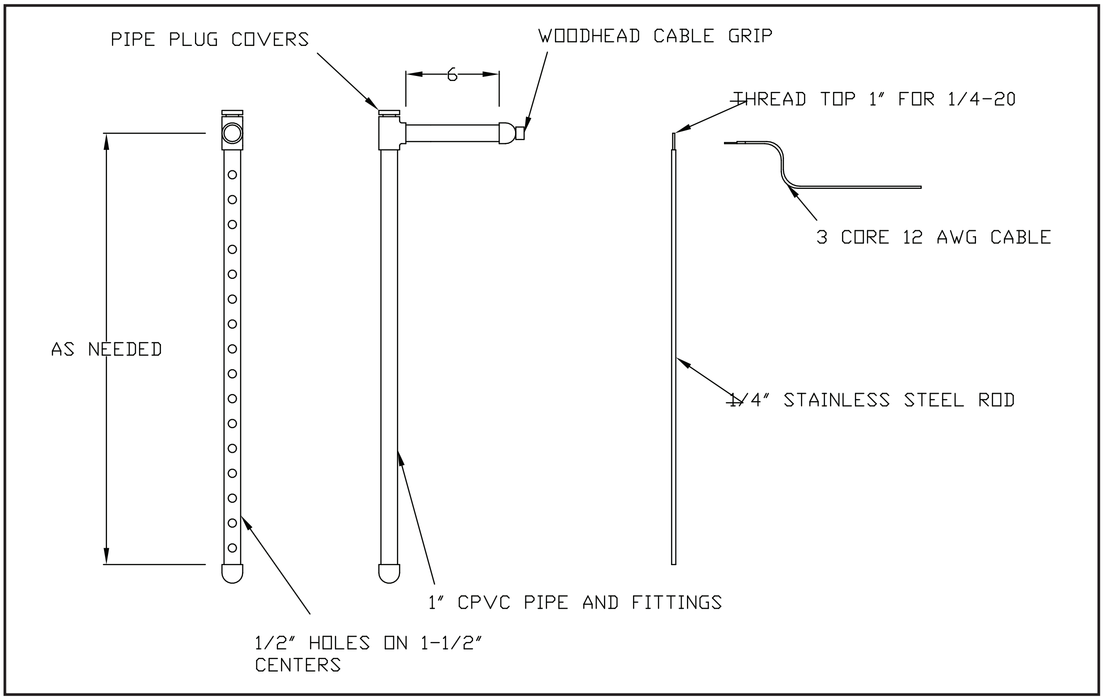
The cathodes should have an exposed area equal to approximately 1/2 percent of the area of the tank and its components. Typically, a 1/4 inch (6 mm) diameter, stainless steel rod, extending from the top lip to 6 inches (150 mm) above the tank bottom at one or more corners, is adequate for current distribution.

Figure 3
Reference Electrode



Typically, one cathode is adequate for tanks whose capacity is less than 100 gallons (400 liters). For most larger tanks, two cathodes in opposite corners are usually enough to provide adequate potential distribution. With tanks longer than about 8 feet (2½ meters), however, it is good practice to install a third cathode at approximately the middle of the length of the tank. Also, with more cathodes, nickel will build up slower and they will have to be stripped the less often.

Figure 2
Typical Cathode

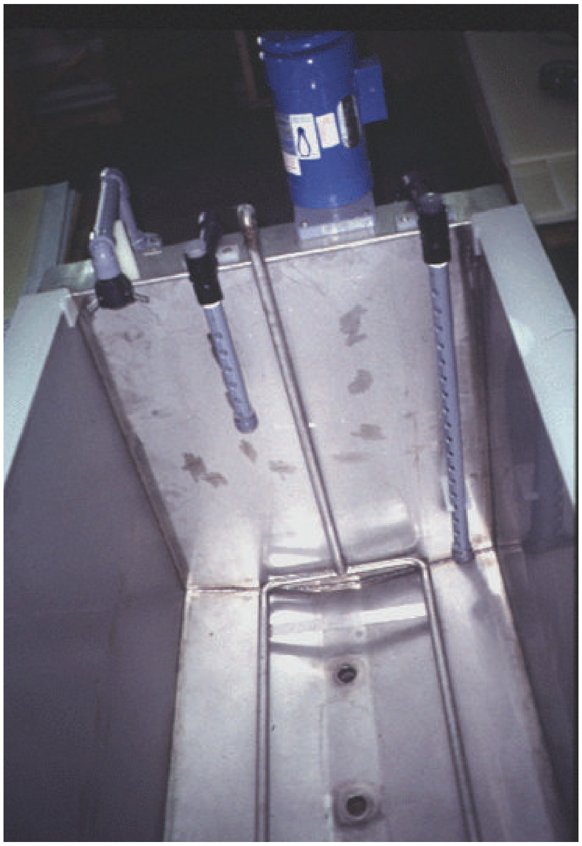


The cathodes and the reference electrode must be insulated from the tank and the work being processed. This is usually accomplished by enclosing the cathodes inside a perforated, 1 inch diameter CPVC pipe.

The holes in the pipe should be pointed away from the tank wall or other stainless steel component. If the cathodes and reference electrode are insulated in this way, the distance between them and the tank wall is not critical. It may be reduced to as little as 1 or 1½ inches. If, however, the cathodes are bare, they must be separated by at least 6 inches (150 mm) from each other and from the tanks walls.

It is good practice to cover the lips of the tank with an insulator to prevent electrical contact between the tank and the work being plated.

Figure 5
Typical Completed Installation



A 1/2 inch (12 mm) thick layer of polypropylene is usually effective for this purpose. A typical completed installation is shown in **Figure 5.**

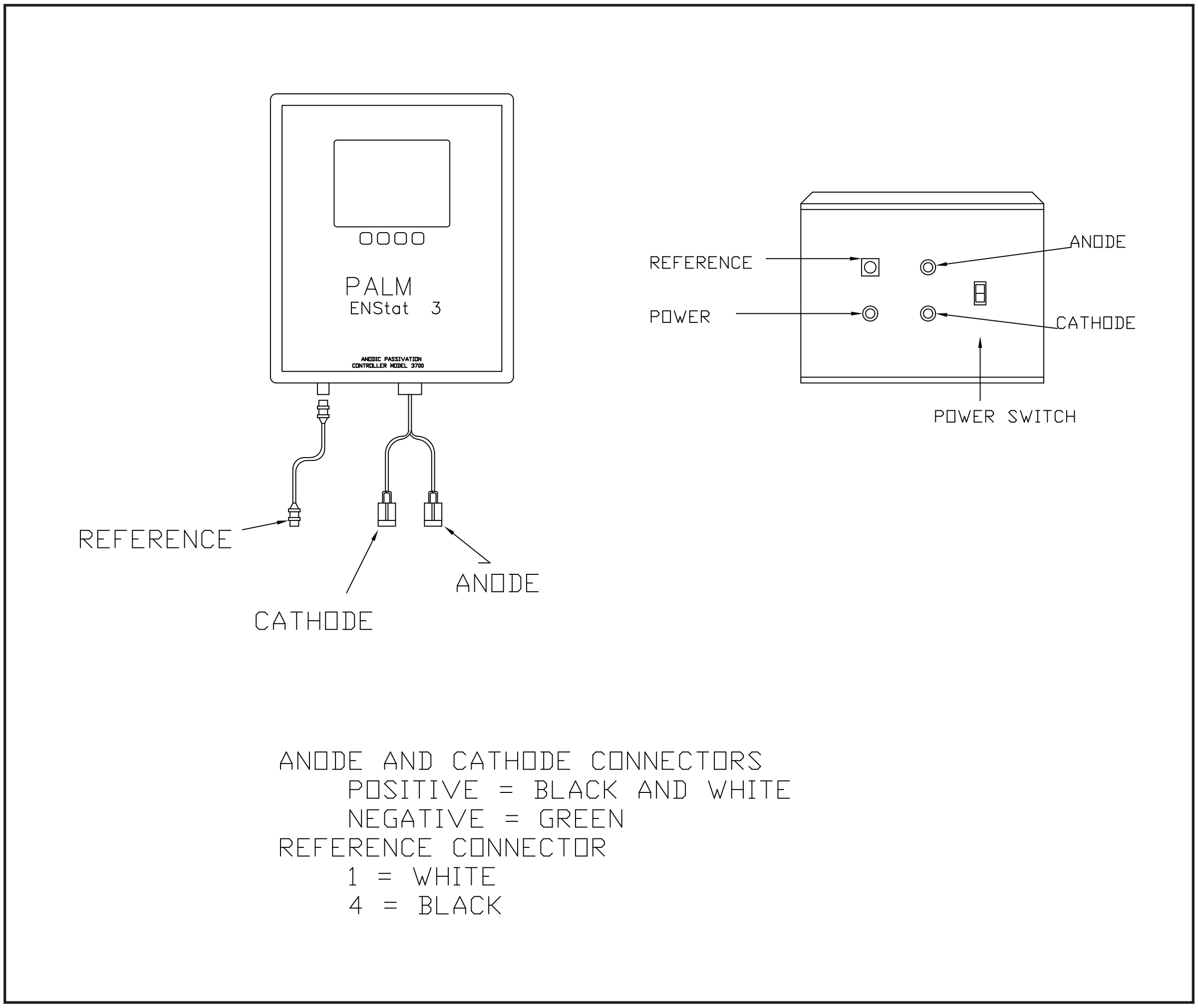
NOTE: It is also good practice to insulate anodically passivated plating tanks from other process tanks and electrical equipment. Stray electrical currents may effect the operation of the **ENstat 3** and may also cause bath operating problems and coating defects. The tank can be insulated by placing a 1/2 inch thick layer of polypropylene between its legs and ground. With steam or hot water heated tanks, insulated couplings should be installed in the supply and return piping.

STEP 4: Attach the anode cable to the tank as is also illustrated in **Figure 1**. The anode cable, normally supplied with the **ENstat 3** controller, is a 15 feet (4½ meter) length of 3 core, 12 AWG cable, with a CC10-25 solder lug on one end and a red battery type, quick disconnect connector on the other. The solder lug must be securely bolted to the tank so that it is free of resistance.

STEP 5: Route the anode and cathode cables from the tank back to the controller enclosure so that they will be protected from mechanical abuse and chemicals. If supplied by Palm, the cable from each cathode is normally a 15 feet (4½ meter) length of 3 core, 12 AWG cable, with a grey battery type, quick disconnect connector on its end. If two or more cathodes are provided, a two cable to one cable (or three to one, etc.) “Y” type adaptor connection will also be provided. It is usually easiest to locate this adaptor connection next to the controller enclosure.

STEP 6: Connect the anode and cathode cables to their respective connections on the bottom of the controller enclosure. The **ENstat 3** is supplied with two 12 inch (30 mm) long pigtails for the anode and cathode cables.These pigtails end with battery type, quick disconnect, connectors, which match the connectors on the cables. The connector for the anode cable is red, while that for the cathode cable is grey. The location of these pigtails is shown in **Figure 6.**

Figure 6
Electrical Connections



NOTE: The arrangement of the three core wires inside the anode and cathode cables is critical. The black and white wires carry current to and from the tank, while the green wire is used to measure potential. These two circuits must be kept separate until they are joined at the tank. If the cables must be lengthened, any new joints must be well made and insulated. If additional connectors are added, the black and white wires should be soldered to the positive terminal, and the green wire to the negative terminal.

STEP 7: Route the cable from the reference electrode from the tank back to the controller enclosure so that they will be protected from mechanical abuse and chemicals. The reference cable is a 15 feet (4½ meter) length of shielded, three core cable with a male AMP 4 pin, plastic shell connector at its end, as shown in **Figure 3.**

STEP 8: Connect the reference cable to the female AMP 4 pin, shell receptacle on the bottom of the controller enclosure. **Figure 6** shows the location of this receptacle.

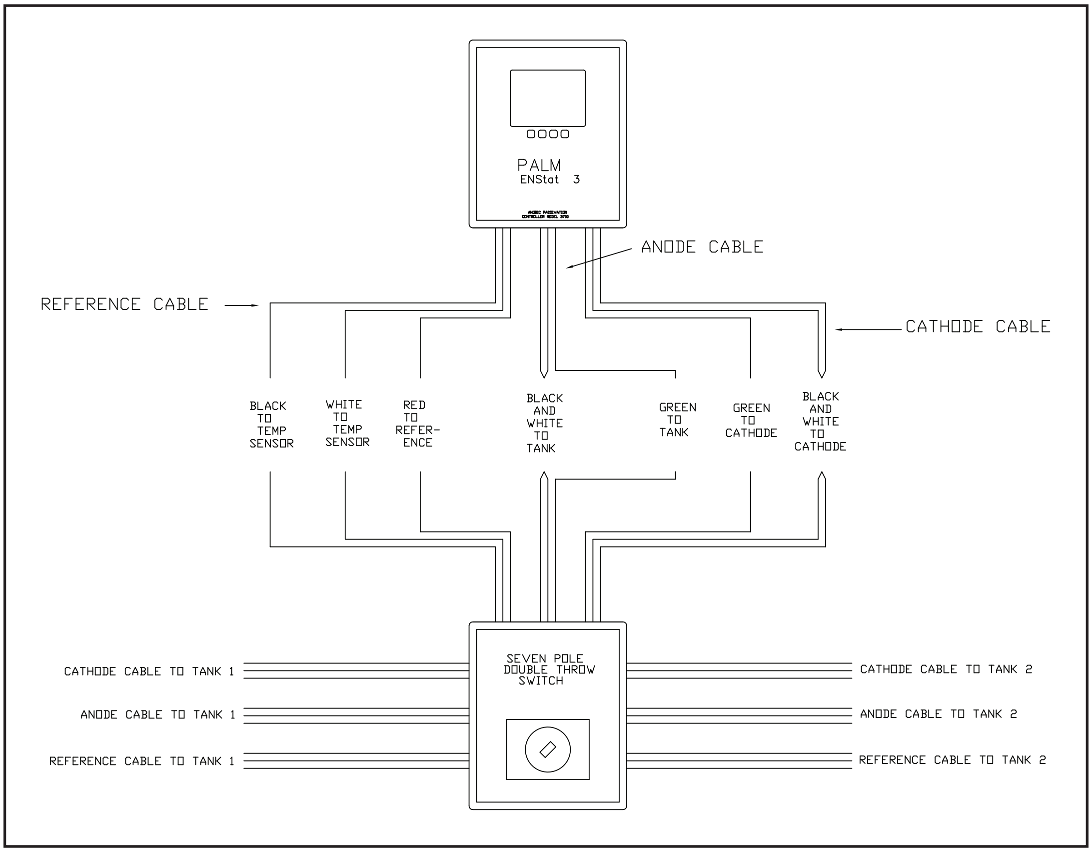
NOTE: The arrangement of the three core wires inside the reference cable is also critical. If this cable must be lengthened, any new joints must be well made and insulated. The red, black and white core wires must be kept separate from each other. If additional connectors are added, the red wire must be soldered to pin 1, the black wire to pin 2, and the white wire to pin 3. The location of these pins in the connectors is also shown in **Figure 3.**

NOTE: It is possible to use the **ENstat 3** to protect two electroless nickel plating tanks, if they are used alternatively. The **ENstat 3**, however, **cannot** be used to protect two tanks operating simultaneously. To use the controller with a twin tank system, a seven pole, two position switch should be installed to allow the tank to be protected to be selected. A wiring diagram for this arrangement is shown in **Figure 7.** The Model 2702 switch is available from Palm for this purpose.

STEP 9: Connect the power cable from the controller enclosure to a *fused*, 15 ampere power supply (120 volt, or optional 240 volt).

STEP 10: After all of the components have been installed and connected, and the operator is ready to turn the controller on,

Figure 7
Installation for a Twin Tank System



STEP 11: Proceed to **Section IV** on ***Initializing the System.***

Section IV
Initializing the System

After the **ENstat 3** has been installed, the controller must be initialized and set up for the new application. Only a few steps are required to complete this process. The new tank's operating parameters must be added to the operating program. These steps are described in the following paragraphs.

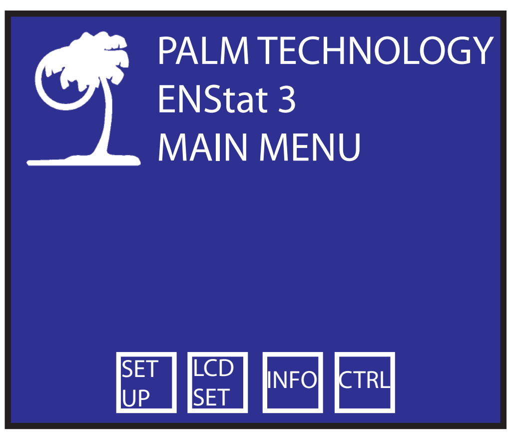
Setting Tank Operating Parameters

The **ENstat 3** controls the tank's potential based on the reference setpoint it also can sound low and high current alarms. This information must be entered into the operating program. This information is entered through the setup parameters menu. Use the following procedure to enter this information.

Enter the reference set point, low current alarm point, high current alarm point and the shut down timer into the controller's operating program by the main menu by pressing the following keys:

Main Menu > Setup

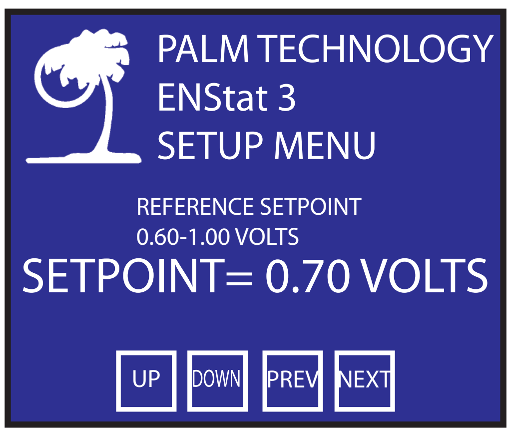
The LCD display MAIN MENU will look like this:



Reference Setpoint:

This is potential at which the controller will maintain the stainless steel tank and its components. The optimum potential to prevent plate-out will vary depending on the tank, the type of stainless steel used to build it, and the electroless nickel plating bath being used. The higher this potential is set, the more nickel will deposit on the cathodes and the more frequently they must be stripped. Too low a potential, however, will reduce the effectiveness of the system and will require the tank to be passivated with nitric acid more often. The optimum value may be established as the user's experience with the system grows. A potential between 0.70 and 0.90 volt is usually satisfactory for most plating tanks operating with acid type, electroless nickel solutions used to apply medium and high phosphorus deposits. With neutral solutions used to apply low phosphorus deposits another potential range may be required. Section VIII on Theory of Operation contains more information on potentials.

Press the up and down key to enter the desired value for reference set point. As a safeguard, the controller will only allow a set point between 0.60 and 1.00 volts to be entered.



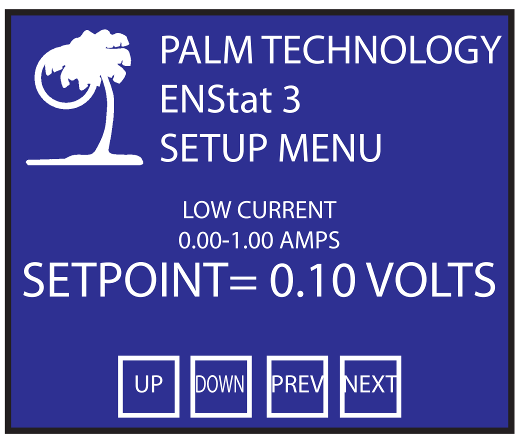
Press the NEXT key to continue the setup:

Low Current Setpoint:

The low circuit alarm warns the user of a fault in the protective circuit (such as a disconnected cable or high resistance connection). The low current alarm point is the current in amperes that triggers the alarm. Most electroless nickel plating tanks need at least 0.5 ampere for protection, so the default value for this alarm point is set at 0.2 ampere. This is especially true for smaller tanks and those that have been polished.

Also, the current required for protection will decline as the bath's temperature drops overnight. For these tanks, it may be necessary to set the alarm point at a lower value or to zero to disable the alarm.

Press the up and down key and enter the desired value for low current alarm point. As a safeguard, the controller will only allow an alarm point between zero and 1.00 ampere to be entered. If a value outside this range is entered, an error message will be displayed.

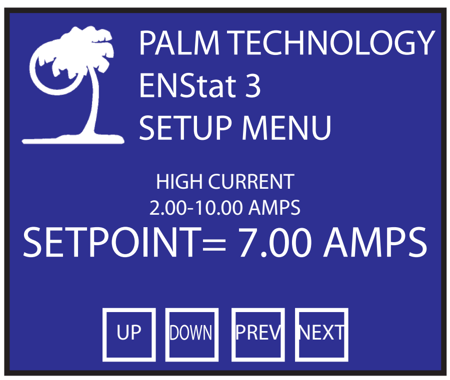


Press the NEXT key to continue the setup:

High Current Setpoint

The high current alarm warns the user of a fault in the protective circuit, such as a short between the tank and the cathodes. Some users also use current as an indication of the tank's condition and of the need to transfer the bath and passivate the tank. The terminal current before the tank must be passivated will vary depending on the tank and the electroless nickel plating bath being used. This value may be established as the user's experience with the system grows.

Press the UP and DOWN key and enter the desired value for *high current alarm point*. As a safeguard, the controller will only allow an alarm point between 2.00 and 9.00 amperes to be entered. The controller will auto regulate is output voltage if a current of more than ten amperes is measured.

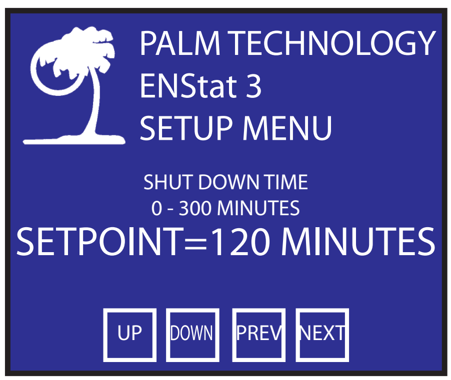


The LCD display will then show:

Shut Down Time

The **ENstat 3** can turn itself off after a preset time from the control screen. With some electroless nickel solutions, the plating rate or stability can be reduced because some additives plate-out or breakdown in the presence of anodic passivation. This seems to occur most commonly overnight, when the bath is cool and not being replenished. If the controller shuts down after the bath cools, it can also eliminate this potential problem.

Press the UP and DOWN key and enter the desired value for *cool down timer shut down point.* Once in the control screen and the unit is operating, there is a cool down key. Once pressed the ENStat will continue to operate for this period of time then shut down. After all of the system parameters have been entered, the LCD display will return
to the main menu screen.



Passivating the Plating Tank

After the **ENstat 3** has been installed and initialized, but before it is turned on, the plating tank should be passivated. Fill the tank with a 30 percent nitric acid solution and then neutralized it as described in **Section VI**. This action will insure a clean surface for the instrument to protect and will reduce the current required from it.

During the passivation operation the ***ENstat 3 must be turned off.*** **Operating the system while the tank is filled with nitric acid will cause rapid corrosion of the stainless steel.**

Preparing the Cathodes and Reference Electrode

Once the plating tank has been passivated and the electroless nickel solution has been transferred into the tank, heat the bath to at least 150°F (65°C). Then careful clean the stainless steel cathodes and reference electrode and activate them with a Woods or sulfamate nickel strike. The strike is necessary to ensure that they begin plating and to provide good adhesion. Then, place them into their respective holders. The nickel struck cathodes and reference electrode should begin plating on their own with electroless nickel. A steady stream of hydrogen gas bubbles from the cathodes and reference electrode shows that they are plating.

NOTE: The **ENstat 3** will not operate properly and will not protect the tank if either the cathodes or reference electrode are not electroless nickel plating. Further, the instrument does not have sufficient output voltage to initiate electrolytic nickel plating on its own. For those facilities that cannot strike stainless steel, plain steel cathodes are available. The design of this reference electrode is shown in **Figure 4.**

Occasionally, with some electroless nickel plating baths and some tanks, nickel struck cathodes and reference electrode will not start electroless plating on their own. It may then be necessary to strike them with a small amount of current in the plating tank. A small battery charger or rectifier set at 5 to 6 volts output can be connected between the stubborn cathode or electrode and an anode and a few amperes trickled on it for 30 to 60 seconds. Electrical connection to the cathode and reference can be made by removing the plug at the top of its holder.

NOTE: If the cathodes and reference electrode are struck with an external rectifier, the **ENstat 3** must be electrically isolated from the tank by disconnecting the anode, cathode and reference cables at the controller enclosure.

The system is ready to protect the plating tank from plate-out. Proceed to **Section V** on ***Operating the System.***

Section V
Operating the System

After the **ENstat 3** has installed and setup and the tank and electrodes prepared, the controller is ready to begin protecting the electroless nickel plating tank from plate-out. Refer to **Figure 7** for a view of the instrument and its controls.

When the controller is first turned on (when the power switch beneath the controller is flipped to the on position), the LCD display will show the main menu screen.

When the CTRL key is pressed, the controller will go into control mode sreen.

After the CTRL key is pressed, the user must press the Run/Stop key for the controller will begin to supply current to the tank to raise its potential to the *reference set point*.

The LCD display will show a message similar to:

REFERENCE = 0.70 VOLT
OUTPUT = 0.72 VOLT
CURRENT = 2.34 AMPS

Because the controller is constantly varing the output voltage based on the potential of the tank, their readings may fluctuate. This is normal for Anodic protection.

however, the reference voltage should remain near the *reference set point.* Once the proper output voltage has been established, no further adjustment by the operator is necessary.

After the controller is first put into control mode and begins protecting the tank, its current may climb to 3 to 5 amperes, as the stainless steel is polarized. After this process is completed, however, the current demand may drop to only a few amperes.

Similarly, the current may temporarily increase if a part is dropped accidentally into the tank. It will return to its normal level, however, after a few minutes as the part becomes passivated. The system will also passivate any dust or dirt that settles onto the bottom. The presence of parts or dust will not necessarily cause the stainless steel to start plating. Thus, the solution does not always have to be transferred to allow the part to be retrieved or the tank to be cleaned. As debris collects on the tank's bottom, however, the current required for passivation will increase slowly, and may be used as a measure of the tank's condition. As the current increases so will the controller's output voltage.

Once the system has been energized and the tank passivated, the **ENstat 3** should usually always remain on, and the tank filled with solution even when it is cold. Otherwise, protection of the system may be lost. The only exceptions are those electroless nickel solutions, whose plating rate or stability is reduced by the plateout or breakdown of additives by anodic passivation. This occurrence can usually be avoided by shutting the controller down overnight. The controller can automatically shut itself down as the bath cools as described in the Shut Down Setpoint timer in Section IV. The operator can initiate the timer by pressing the cool down button on the control screen while in Run mode. The unit will then automatically shut down after the timer has elapsed.

Otherwise, the **ENstat 3** should only be turned off when the bath is transferred and the tank contains nitric acid. **Operating the system while the tank is filled with nitric acid will cause rapid corrosion of the stainless steel.**

Controller Alarms

The **ENstat 3** includes alarms for out-of-limit conditions. An audible alarm will sound for 10 seconds each time the controller detects an low current, or a high current condition. In addition, the controller will display the alarm below the voltage and current readings.

The noise from the alarm can be stopped by pressing the mute key. The mute key will silence the speaker, but it will not stop the control cycle. The mute is underlined when active and will reset itself upon exiting the control screen or pressing the mute button.

Shutdown

The **ENstat 3** can turn itself off after a user determined period of time called cool down time. This is useful for the following reason. Some electroless nickel solutions, plating rate or stability can be reduced because some additives plate-out or breakdown in the presence of anodic passivation. This seems to occur most commonly overnight, when the bath is cool and not being replenished. If the controller shuts down after the bath cools, it can also eliminates this potential problem.

If this function is used, the operator can press the cool down button during operation and the unit will continue to operate until the time has elapsed. Once the time has elapsed the unit will shut down the anodic powersupply.

Section VI
Maintaining the System

The **ENstat 3** is a precision electronic instrument, which requires little maintenance, other than periodic cleaning. The controller is supplied in a water tight, NEMA 4, plastic enclosure, which protects its components from normal plating environments.

The controller's electronic components are unlikely to fail, but can be broken by rough handling. Under normal conditions, the operator should not have to open the controller enclosure. If this should be necessary, however, always disconnect the power supply to the controller and be very careful when handling the circuit boards, LCD display, and other components.

The cathodes and reference electrode will require periodic stripping to remove the electroless nickel plated onto them. Provided the cathodes are of adequate size and are properly prepared to ensure adequate adhesion, stripping should not be required more often than weekly. They should be visually inspected periodically, however, to check for buildup and for flaking. Poorly adherent deposits falling onto the bottom of the tank will increase the current required from the instrument and may affect the quality of the plating.

NOTE: Plain steel cathodes and reference electrodes cannot be easily stripped and reused. Rather they should be replaced when the nickel layer on them becomes too great. If the thickness of the coating is allowed to grow out of the holes in the CPVC holders, the effectiveness of the anodic passivation system can be reduced. Replacing cathodes or a plain steel reference electrode is described in **Section XI.**

The following is a spare parts list for the **Model 3700** controller.

Part Number	**Description**
Circuit Boards	
3700-LCD	LCD replacement
3700-PWS	Power supply
3700-CPU-MOD	CPU module
Other Components	
3700-REF	Reference electrode
CATHODE	Cathode
A-CABLE	Anode cable
C-CABLE	Cathode cable
QDC	Quick disconnect connectors
SWITCH	Two position, twin tank switch

Tank Passivation

While the **ENstat 3** will prevent plate-out of stainless steel tanks, it does not stop the accumulation of dust, dirt, metal particles, or other debris. Accordingly, it is good practice to periodically transfer the solution, and to clean and passivate the stainless steel with 30 percent nitric acid.

Caution: the ENstat 3 must be turned off whenever nitric acid is present, or severe corrosion of the stainless steel will occur.

The frequency of cleaning depends upon the quantity of soils introduced and upon the amount of solution filtration. Most electroless nickel plating systems, however, can be operated for two or three weeks or sometimes even months before cleaning is needed. The following procedure for tank cleaning may be helpful.

STEP 1: After operation is complete, transfer the electroless nickel plating solution to another clean plating tank or a clean storage tank. The solution should be completely filtered during the transfer by securely attaching a 1 :m filter bag to the end of the transfer hose or pipe. The heater in the plating tank must be turned off before transferring the solution.

STEP 2: If the temperature of the solution is above 150°F (65°C) after the transfer has been completed and enough deionized water has been added to return the bath to its normal operating level, the air agitation should be turned on in the second plating tank.

STEP 3: After the solution cools below 150°F (65°C), the air should be turned off. The heater and the air should not be left on unattended overnight. Plating solution should not be transferred to a storage tank if its temperature is above 150°F (65°C). If an external heat exchanger is used, the plating solution can be cooled before transfer by circulating cooling water through it.

STEP 4: Open the drain on the emptied plating tank and rinse the components with water to a proper waste treatment facility. Alternatively, the rinse water can be collected and returned to the plating bath. Residual plating solution left in the tank will shorten the effectiveness and life of the nitric acid passivation solution and should be removed.

STEP 5: Close the drain on the empty plating tank and fill it with a 30 percent by volume solution of nitric acid (42°Be) in water from the storage tank. More concentrated nitric acid solutions should not be used for passivation.

NOTE: If plain steel reference electrode and cathodes are used instead of stainless steel, they must be removed before the nitric acid solution is placed in the tank. Plain steel will be rapidly attacked by the nitric acid solution and toxic nitrous oxide fumes may be generated. Using snap type holders to support plain steel electrodes is best so that they can be easily removed and reinstalled.

STEP 6: The nitric acid solution must not be heated. Heating will cause any plastic components to oxidize rapidly and may produce toxic fumes.

Caution: The ENstat III must be turned off whenever nitric acid is present, or severe corrosion of the stainless steel will occur.

The level of the nitric acid passivation solution in the plating tank should always be above the highest working level of the plating solution. If an external bag or cartridge filter chamber is used, ensure that it is completely filled with acid.

STEP 7: Turn on the pump to circulate the nitric acid solution to ensure its contact with all parts of the plating system exposed to the electroless nickel bath, including the pump, heat exchangers and filters. A filter bag or extension pipe to below solution level must be attached to the pump outlet during circulation to reduce splashing of the acid.

STEP 8: The pump should be left in operation for about two hours and then shut down. Allow the nitric acid solution to remain in the tank overnight, or until the tank and its components are clean and passivated. It is usually helpful to periodically turn the pump on and off during passivation to supply fresh acid to externally mounted components like exchangers and filters.

The tank should be covered and the ventilation exhaust should be left on while the tank is being passivated. The reaction of nitric acid with any nickel remaining in the system may generate toxic nitrous oxide fumes.

The small diameter hole above the solution level in the air sparger riser should be checked periodically to ensure that it has not become plugged. This hole is required to allow nitric acid and rinse water to rise into and clean inside the pipe. It also acts as a siphon beaker and protects the blower or air system from electroless nickel and nitric acid solutions.

STEP 9: Once passivation is complete, pump the nitric acid solution back into its holding tank, after making sure that the drain valve on the storage tank is closed. Open the drain on the plating tank and thoroughly rinse the tank with tap water to a proper waste treatment facility. The lips of the tank, and the area behind the heater and air sparger, must also be rinsed.

STEP 10: Close the drain and fill the tank to above the highest level of the passivation solution with tap water. Add a small amount of concentrated ammonium hydroxide or potassium carbonate. Turn on the air agitation and the pump to mix the alkali and to neutralize residual acid in all parts of the plating system.

Check to be sure that the water is alkaline (pH 7 or higher). If the pH is low, add more ammonium hydroxide or potassium carbonate and continue to circulate the water. While wearing protective gloves, wipe the tank above solution level and the lips with a sponge soaked with neutralizer rinse. Drain the tank to a proper waste treatment facility and thoroughly rinse it with deionized water, being sure to flush external pumps, filters and exchangers. The tank is now clean and ready to accept plating solution.

STEP 11: If the electroless nickel plating solution has been stored in a holding tank, it should be filtered through a 1 micron bag filter as it is returned to the plating tank.

NOTE: Before using or handling any chemicals check with your supplier for safe handling techniques and read the appropriate material safety data sheets.

Stripping the Cathodes and Reference Electrode

If the cathodes and reference electrode cannot be completely stripped during tank passivation, they should be removed from the tank and stripped in a separate nitric acid solution. To make stripping easier, with electrodes supplied by **Palm**, the lower shield (the perforated 1 inch CPVC pipe) can be unscrewed from its connecting tee or ell and slipped off from around the electrode. The exposed rod or thermoweld can then be immersed into the stripping solution.

NOTE: Plain steel cathodes and reference electrodes cannot be easily stripped and reused. Rather they should be replaced when the nickel layer on them becomes too great. Replacing cathodes or a plain steel reference electrode is described in **Section XI.**

Section VII
Troubleshooting the System

The **ENstat 3** is designed to provide nearly trouble free operation for years of service if operated properly. However, all equipment will require service at some point in time. The following information may help to identify the source of problems and to correct them quickly.

Faulty Circuits and Connections

Faulty measurements can result if fumes are allowed to enter the controller enclosure. Chemical fumes can attack the circuit boards, breaking traces or creating short circuits, which can result in improper operation. The controller should be located in an area away from traffic, steam, harmful vapors and potential damage.

To ease assembly and repair, the different components in the controller are connected with cables and plug-in connectors. Plating shop fumes can corrode these contacts leading to poor connections and to faulty readings. Check the connections inside the controller enclosure between all of the circuit board boards. They should be clean and tightly connected. Clean the contacts only when absolutely necessary. Mechanical cleaning can damage the connector or its cable. It is better to spray the contacts with contact cleaner spray.

Also, check the quick disconnect connectors on the pigtails beneath the enclosure, and the plastic shell connector on the reference cable, as well as their connections to the tank and cathodes. A resistance of only a few ohms can severely reduce the current from the controller and its ability to protect the tank.

Meter Fluctuations

Fluctuations in the last digit of digital meters are normal and should be ignored. Larger fluctuations, however, may suggest one of the following conditions.

A. Changes in solution or work agitation may cause small changes in the output current and voltage. This is a normal condition.
B. If large increases in output current occur along with increases in output voltage, the reference electrode may be intermittently contacting the tank.
C. Smaller increases in the current and output voltage may indicate that the reference electrode is coming in and out of contact with the solution.

Low Current

The *Low Current* indicator and the audible alarm are triggered by very low output current. The *Low Current* light and alarm turn on when the current drops below the low current alarm point entered into the operating program through the setup parameters menu. The default value for this alarm point is 0.2 amperes. These conditions can be due to several factors.

A. New, well passivated tanks, may require only a small amount of current to keep the tank from plating. This is especially true for smaller tanks and those that have been polished.
B. When the tank is inactive and the bath has cooled to less than 150°F (65°C), little or no current is required to maintain passivity. This is a normal condition.
C. The cathode cable is not properly connected to the cathodes, or the connection resistance is very high. A resistance of only 5 to 10 ohms in this circuit will cause the output current to fall to near zero. Resistance in the cathode circuit will also cause the reference voltage to fall below the reference set point and the output voltage to climb to its maximum value, about 2.5 volts.
D. The cathodes are not electroless plating. The controller does not have sufficient output voltage to initiate electrolytic nickel plating on its own. Thus, if the cathodes are not electroless plating, they cannot accept current from the tank.
E. The anode cable is not properly connected to the tank, or the connection resistance is very high. A resistance of only 5 to 10 ohms in this circuit will cause the output current to fall to near zero. Resistance in the anode circuit, however, has little effect on the reference or output voltages.

Current Is Low and Cannot Be Adjusted

If the output current is low (but greater than zero) and cannot be adjusted upwards, the cathodes probably are not electroless plating. The **ENstat 3**’s output voltage is not high enough to overcome the overvoltage for nickel and to initiate plating. The electrodes must be carefully cleaned and activated with a nickel strike for the **ENstat 3** to operate properly. See also the *Shorted Part Test* described below.

Shorted Part Test

If the current from the **ENstat 3** is low, but the cathodes and reference electrode are plating correctly, it may only be that the tank needs very little current for protection. Some tanks and some baths can be properly protected with very low amounts of current, especially when they have been freshly passivated with nitric acid. Use the following procedure to confirm that the **ENstat 3** is properly protecting the tank at low current levels:

STEP 1: With the electroless nickel bath operating normally and with the **ENstat 3** in automatic control mode, electrically connect a plating steel part or panel to the tank. This is most easily accomplished by touching the part or panel against the tank wall beneath the surface.

STEP 2: Observe the current being discharged from the **ENstat 3**. If the system is operating properly, the current should jump to 1 to 2 amperes when the part is in contact with the tank. When the part is removed, the current will drop back to its original level.
If the current from the unit does not climb when a part is touched to the tank, the system is not operating properly. It should be inspected for proper wiring and connections and for plating of the cathodes and reference electrode. Most likely it will be found that the cathodes are not electrolessly plating.

STEP 3: Remove the shorted part or panel from the plating tank.

The Cathodes or Reference Electrode Are Not Plating

The **ENstat 3** will not operate properly and will not protect the tank if either the cathodes or reference electrode are not electroless nickel plating. The controller does not have sufficient output voltage to initiate electrolytic nickel plating on its own. Typically, the output current will be zero or near zero if the cathodes are not plating, and maximum (approximately 10 amperes) if the reference is not plating. Use the following guide to check for this condition.

STEP 1: Observe each cathode and reference electrodes to see if bubbles are evolving from the stainless steel rods or tube. If the bath is at operating temperature, a steady stream of hydrogen gas bubbles from the cathodes and reference electrode shows that they are plating.

STEP 2: Disconnect the anode, cathode and reference cables at the controller enclosure.

STEP 3: Measure the voltage between the tank and cathodes and between the tank and reference manually using digital voltmeter. Electrical connection to the cathode can be made either through the quick disconnect connector on the end of its cable or by removing the plug at the top of its holder. Connection to the reference electrode can be made through Pin 1 on the shell connector on the end of its cable.

STEP 4: If either the voltage between the reference and the tank or between the cathodes and the tank are zero or near zero, the reference electrode or the cathodes are not nickel plated. A meter reading of zero means that the voltmeter is measuring the potential of stainless steel versus stainless steel. The electrodes must be carefully cleaned and activated with a nickel strike as previously described for the **ENstat 3** to operate properly.

STEP 5: If the voltage between the reference and the tank or between the cathodes and the tank is less than or equal to 0.62 volt, the cathodes and the reference electrode are not electroless nickel plating. The electrodes must be carefully cleaned and activated with a nickel strike as previously described for the **ENstat 3** to operate properly.

High Current

The *High Current* indicator and the audible alarm are triggered by very high output current. The High Current light and alarm turn on when the current exceeds the high current alarm point entered into the operating program through the system parameters menu. The default value for this alarm point is 6 amperes. These conditions can be due to several factors.

A. The cathode in contact with the tank creating a short circuit.
B. The parts being plated in contact with the tank or with the cathodes.
C. The reference electrode is in contact with the tank. Any short between the reference or its cable will cause the ENstat 3 to turn on to full output.
D. The reference electrode has stopped plating.
D. The tank is plating out or there are very large number of parts on its bottom.

Output Current Suddenly Increases

If the output current suddenly increases to a high level and the instrument then regulates the output voltage to maintain an output current of 10 amps, either the cathodes were not electroless plating, but then began to plate, or the reference electrode stopped plating.

The **ENstat 3**'s output voltage is not high enough to overcome the overvoltage for nickel and to initiate plating on the cathodes. The small amount of current flowing (typically less than 0.2 amp) is due to hydrogen evolution on the cathodes and not to plating. After several hours of operation, however, electroless nickel plating may begin due to changes in the solution. When electroless plating begins, electroplating will also start and a large current will flow from the **ENstat 3.**

If the reference electrode stops plating, the potential measured by the **ENstat 3** will be less than the reference set point, and the instrument will apply more and more current to try to increase the potential until it shuts itself down.

Tank is Plating Out

If the current from the **ENstat 3** is very high and the reference voltage begins to drop below the *reference set point*, the tank is either starting to plate-out or a large number of parts have fallen to the bottom of the tank. The plating tank should be shut down and the bath transferred to its storage tank, any parts present should be removed, and the tank passivated as described in **Section VI.**

Reference Voltage is Zero

If the reference voltage is zero or near zero, and the output voltage and current are high, either the tank is starting to plate-out (see above) or the reference electrode is not nickel plated (is bare stainless steel). If the reference voltage is zero or near zero and the current flow is also near zero, there is an open circuit or large resistance in the cathode circuit.

Reduced Plating Rate or Stability

The plating rate or stability of some types of electroless nickel solutions can be reduced due to the breakdown of additives in the presence of anodic protection. This most commonly occurs overnight, when the bath is cool and not being replenished. If this condition occurs, enable the automatic shutdown feature by entering a temperature shut down point between 50 and 80°C in the system parameters menu as described in **Section III**. The controller will then shut itself off as the bath cools and turn itself back on when it is again heated up.

Black Cathodes

Black or dark discolored plating on the cathodes is an indication of heavy metals like lead plating out with the electroless nickel. Heavy metals preferentially plate at low current density areas, and the low currents discharged by the **ENstat 3** can never produce more than 10 amp/ft^2 at the cathodes. See also *Reduced Plating Rate or Stability* described above.

Etched Tank

If the stainless steel tank becomes etched or develops a heavy red or brown stain, the cause may be chlorides or fluorides dragged into the plating bath from previous acid or strike solutions. These halogens are concentrated at the tank surface by the ENstat's electrical field and can cause severe corrosion of the stainless steel. Etching has been observed with as little as 30 ppm of chloride in the plating bath. Leaving the ENstat turned on while the tank is filled with nitric acid will also cause severe corrosion of stainless steel.

Technical Support

If the problem still has not been resolved, record the reference and output voltages, current and temperature shown on the LCD display, and the results of the Self Test any voltmeter readings and contact Technical Support at:

Palm Technology, Inc.
1717 JP Hennessey Drive
LaVergne, TN 37086

Voice 615-641-1200
Fax 615-641-1205
email support@palminc.com

Section VIII
System Description and Specification

The **ENstat 3** is a microprocessor controlled potentiostat, specifically designed to protect stainless steel equipment against plate-out in electroless nickel plating solutions. Its individual components and their features are described in the following:

Central Processing Unit

The central processing unit (CPU) is a custom designed microprocessor with a 16 bit analog to digital converter.

Console

The controller enclosure a 4.5” 320x240 graphic LCD display and a 4 key keypad for communication between the operator and the controller.

Program

The operating program (software) was especially written for controlling electroless nickel baths. The program is stored in EPROM. The users variables are stored in RAM that is backedup by a super capacitor during power down. This super capacitor can hold the values in RAM for up to 3 days without power.

Audible Signals

The operating program uses sound extensively to notify the operator of events. Alarms, records, key entries, and errors are announced by the CPU sound generator.

Specifications

POWER INPUT:	
Controller:	100 - 120 or 200 - 240 VAC, 50 - 60 Hz @ 3 or 1.5 amperes
Supply Wiring:	Green = Ground Black = Hot/Line White = Neutral
OPERATION:	
Ambient Temperature:	0 - 50°C
Humidity Range:	5% to 95%
WEIGHT:	
Enclosure:	9 lbs or 4.1 kg

Section IX
Theory of Operation

Clean stainless steel is normally passive in electroless nickel plating solutions and not susceptible to either corrosion or to the deposition of plating. Passivity, however, is lost by galvanic coupling with plating parts, by the present of dirt or debris on the metal, or by either mechanical or chemical abrasion.

Anodic protection prevents chemical reactions, like corrosion or plating, by controlling the potential of the metallic surface. In electroless nickel solutions it serves to prevent the break down of stainless steel’s natural passivity. It strengthens the oxide film upon the surface of the metal and reduces its solubility, in much the same way as does nitric acid passivation.

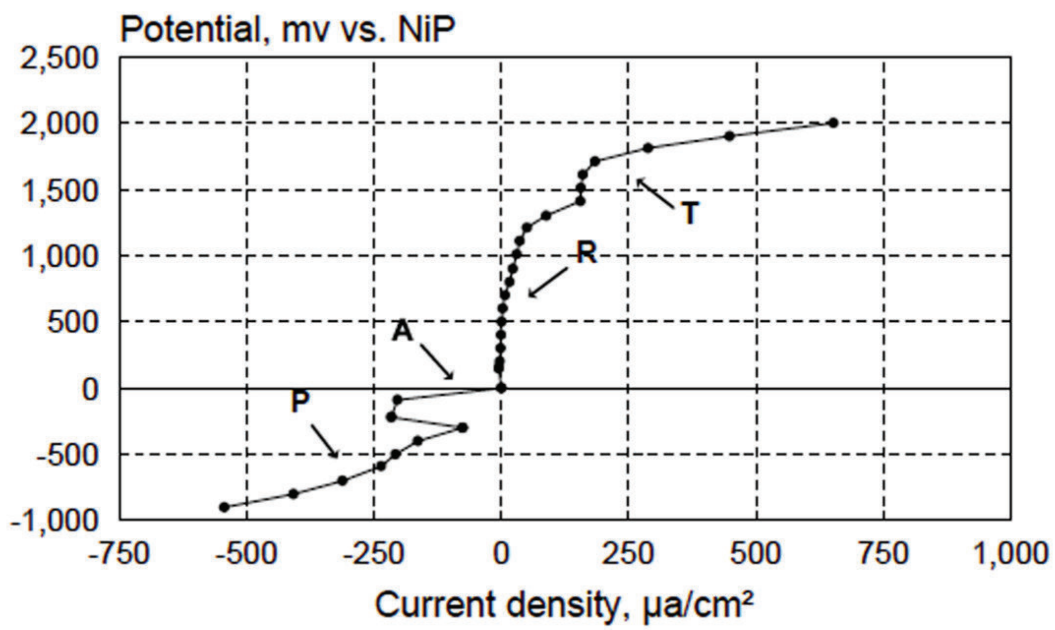
A potentiostat, like the **ENstat 3,** is an electronic device used to anodically protect an electroless nickel plating tank. It maintains the tank (the anode) at a constant potential with respect to a reference electrode by passing a small current between it and the cathode placed into the plating solution.

Anodic protection is only possible for those materials and those solutions whose electrochemical behavior follows the classic active/passive pattern illustrated by **Figure 9**. Fortunately this behavior is typical for stainless steel and titanium in electroless nickel plating solutions.

Polarization diagrams of this type are generated by plotting the current density received or discharged from a metal (which is directly proportional to its plating or corrosion rate) when its potential is controlled versus a reference. The polarization diagram shown in Figure 8 was developed for passivated stainless steel in the traditional Kanigen plating solution, but is typical for acid electroless nickel baths.

Point A on this diagram represents the potential of freshly activated stainless steel (versus a reference of the electroless nickel reaction) just before it begins plating. This is also the active region where corrosion of the metal would occur lacking other influences. As the potential is increased negatively (cathodically) toward Point P, current is applied to the stainless steel and nickel will be electroplated upon it. This is the reaction that occurs on the cathode.

Figure 8
Potentiostatic Behavior of Stainless Steel In Electroless Nickel Solutions



If the potential is forced in the positive (anodic) direction, however, current is reduced and electroplating slows. At Point R the plating reaction is in equilibrium and the oxidation of hypophosphite equals the reduction of nickel.

Point R is also the rest potential of passivated stainless steel in an actively plating solution. Stainless steel will remain at this state, without plating, while its passivation is maintained. If, however, it loses its passivity, its potential will shift toward Point A and plating will begin.

As the potential is increased further in the positive direction, current will decline to zero or negative values, and will stay at this level until the potential reaches approximately one volt. This range is the passive region for stainless steel. Here the metal's surface is covered by a tenacious oxide film that retards corrosion and where plating cannot occur. In this region, most current discharges from the tank through oxygen evolution rather than by metal dissolution. Above Point T is stainless steel's transpassive region where current rapidly increases and where severe corrosion can occur.

Accordingly, if the potential of stainless steel can be controlled within the passive region, both plating and corrosion can be prevented. If not enough current is applied, however, the passivity of the stainless steel will be lost and plating will occur. If the tank discharges too much current, it will be forced into the transpassive region and severe corrosion will occur. Thus, for anodic protection to be successful, careful control of potential instead of current is mandatory.

Section X
Module and Circuit Board Layout Drawings

The following drawings show the location of different components, test points and adjustment points on the different modules and circuit boards used in the **ENstat 3.**

Figure 10
Circuit Board Locations

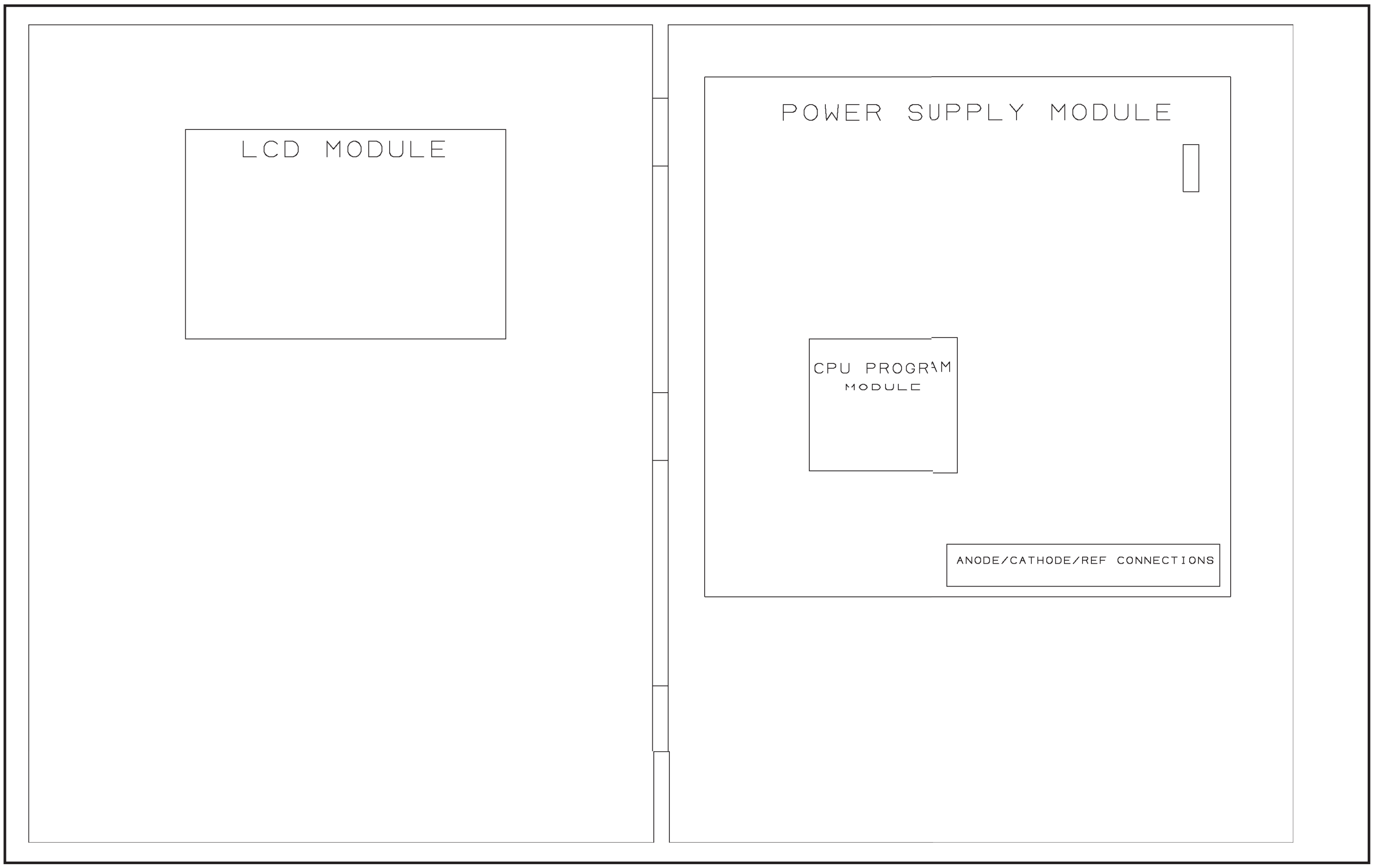


Figure 11
LCD Adaptor Module Layout

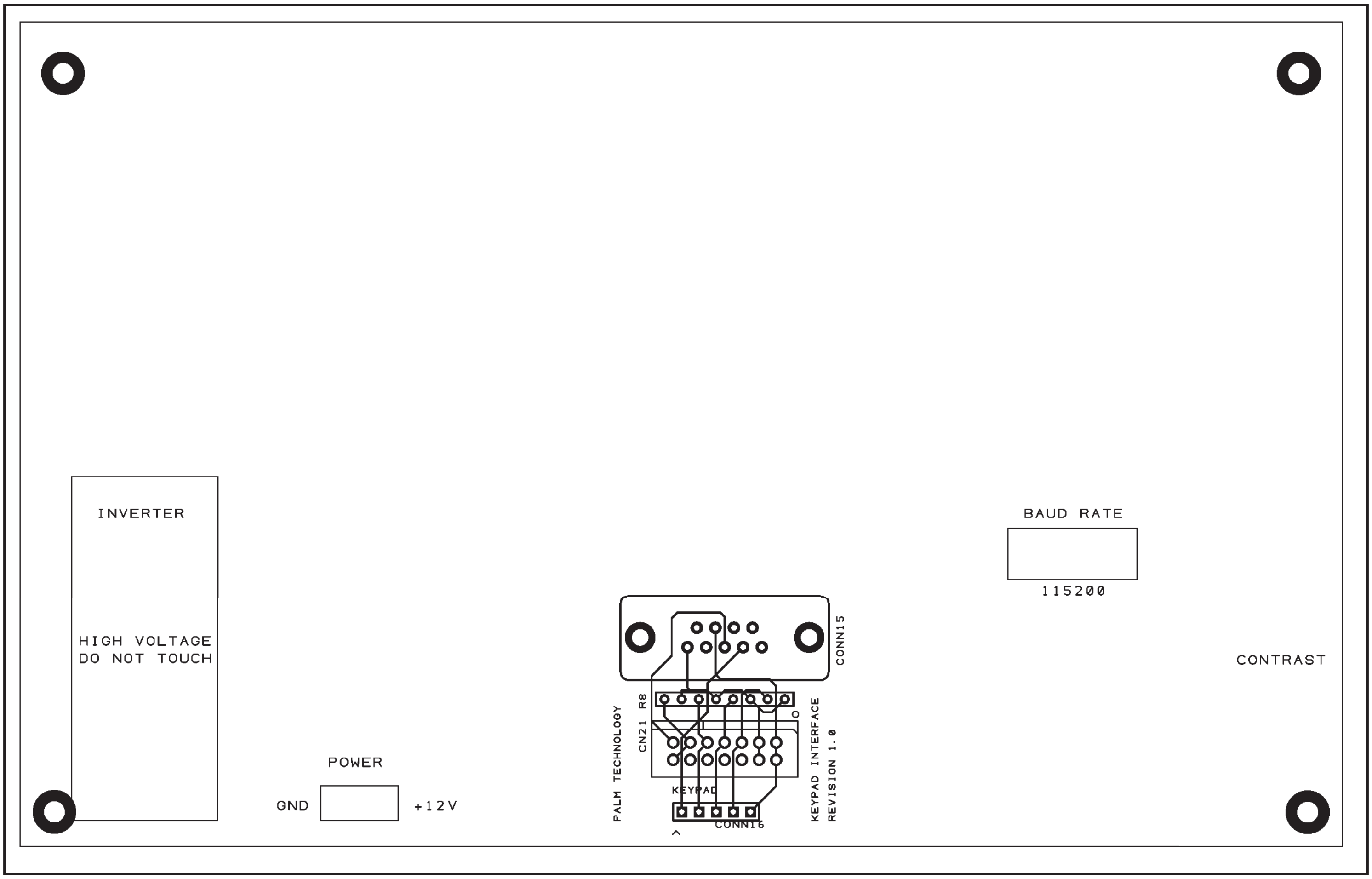


Figure 12
Power Supply Module Layout

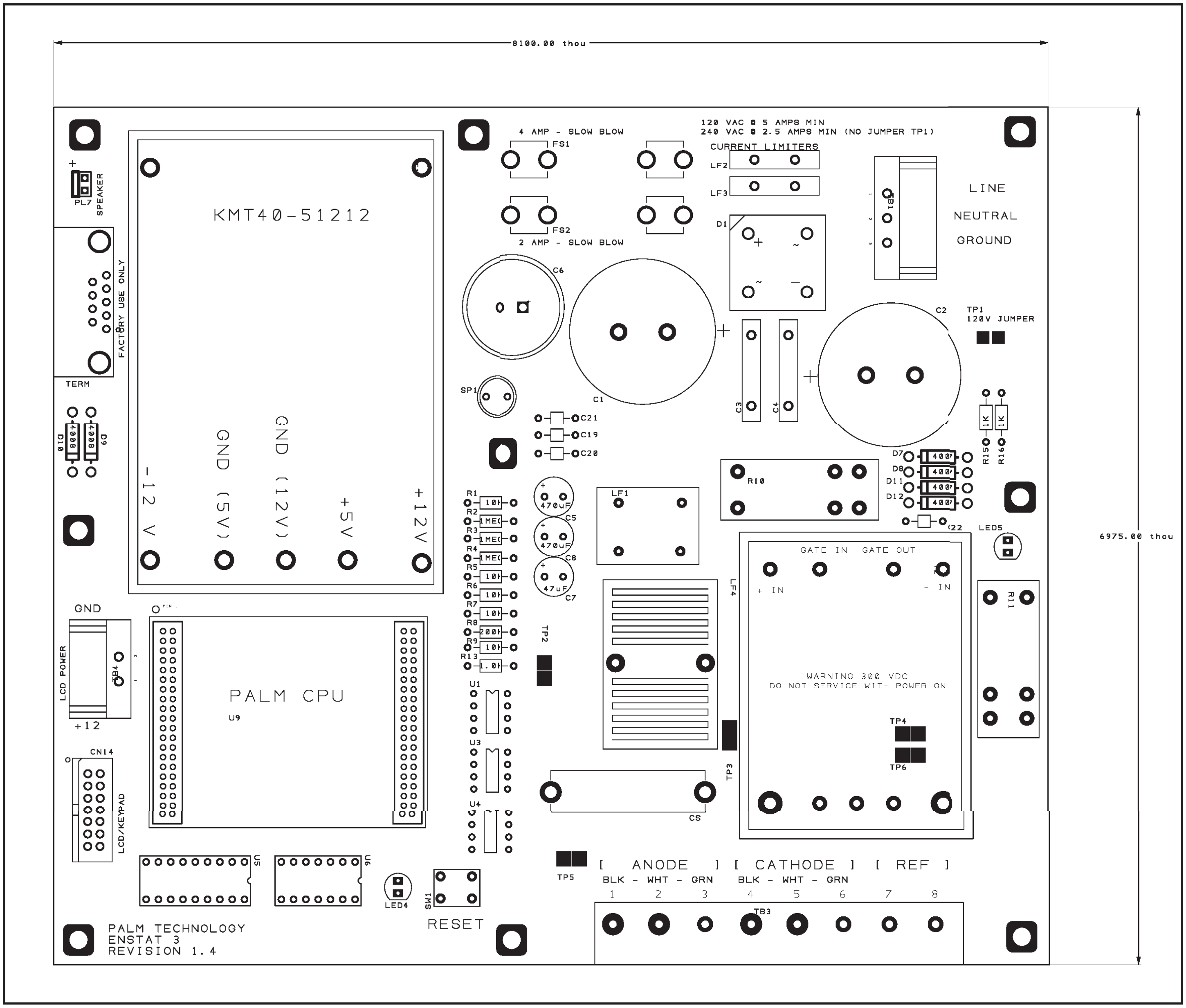
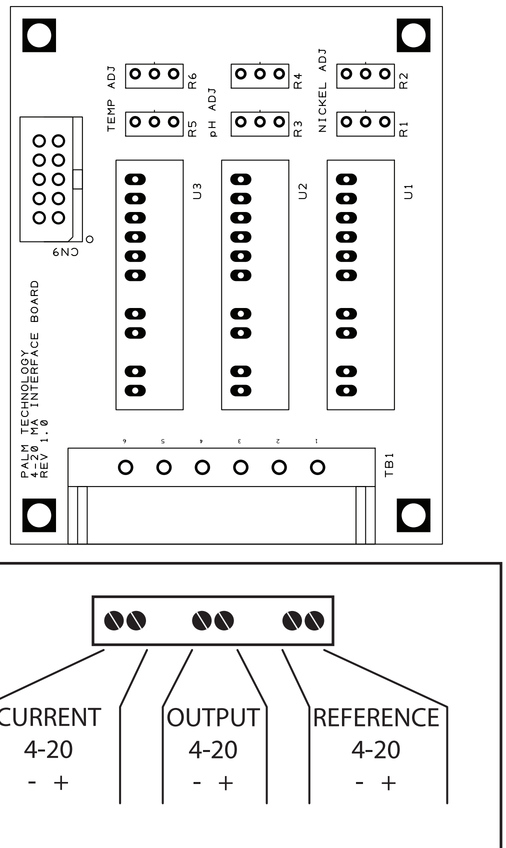


Figure 13
Optional 4-20ma output board



If your ENStat 3 is equipped with a 4-20 mA output card you will find this card in the upper right hand corner of the unit. The 4-20 mA SPAN and TRIM potentiometers have been preset and painted at the factory. If you want to test the output of the card you can use the information screen of the unit to either force a 4 mA output or a 20 mA output.

The 4-20mA outputs operates in the following way.

When the unit is not in control mode all the outputs will be 4 mA. Once the unit is placed in control mode the outputs will be

Reference Voltage:	5-20mA	=	0.0 - 2.0 VOLTS
Output Voltage:	5-20mA	=	0.0 - 2.0 VOLTS
Output Current:	5-20mA	=	0.0 - 10.0 AMPS

Section XI
Replacing Components

Over the life of the controller some of its components may have to be replaced. Use the following procedures to replace the reference electrode, cathodes or plain steel reference electrodes, Program Module. The fuses on the Power Supply Module are not user replaceable and may have 300 volts applied to them even if the controller is turned off and disconnected from its power supply.

Replacing the Reference Electrode

The reference electrode may occasionally need to be replaced. Use the following procedure to replace the electrode.

STEP 1: Remove the old reference electrode from the electroless nickel plating tank. Disconnect the AMP shell connector on the reference signal cable from the receptacle on the bottom of the controller enclosure.

STEP 2: Install the new reference electrode in the electroless nickel plating tank.

STEP 3: Route the cable from the reference electrode from the tank back to the controller enclosure so that they will be protected from mechanical abuse and chemicals. The reference cable is a 15 feet (4½ meter) length of shielded, two core cable with a male AMP 4 pin, plastic shell connector at its end, as shown in **Figure 3.**

STEP 4: Connect the reference cable to the female AMP 4 pin, shell receptacle on the bottom of the controller enclosure. **Figure 5** shows the location of this receptacle.

NOTE: The arrangement of the two core wires and shield inside the reference cable is critical. If this cable must be lengthened, any new joints must be well made and insulated. The shield and the black and white core wires must be kept separate from each other.

Replacing the Cathodes or Plain Steel Reference Electrode

Plain steel cathodes and reference electrodes cannot be easily stripped and reused. Rather they should be replaced when the nickel layer on them becomes too great. Use the following procedure to replace a cathode or a plain steel reference electrode.

STEP 1: Remove the old cathode or reference electrode from the electroless nickel plating tank. Disconnect the cathode cable from the battery type, quick disconnect connector at the bottom of the controller enclosure.

STEP 2: Unscrew and remove the pipe plug cover from the CPVC tee at the top of the holder.

STEP 3: Unscrew and remove the 1/4 - 20 nut from the top of the 1/4 inch diameter rod above the cable lug in the tee. Lift the lug off of the 1/4 inch diameter rod.

STEP 4: Unscrew and completely loosen the Woodhead cable grip from the end of the six inch long horizontal CPVC pipe. Then unscrew the six inch long horizontal CPVC pipe from the side of the tee, and carefully pull the cable and lug out of the tee.

STEP 5: Remove the vertical CPVC pipe from the bottom of the tee.

STEP 6: Unscrew and remove the second 1/4 - 20 nut from the 1/4 inch diameter rod in the tee and carefully pull the old steel rod out of the bottom of the tee and discard.

STEP 7: Insert the threaded end of a new plain steel cathode or plain steel reference electrode through the hole in the bottom of the tee and screw on a 1/4 - 20 nut and tighten it in place.

STEP 8: Screw the vertical CPVC pipe into the bottom of the tee to cover the steel rod electrode.

STEP 9: Carefully push the cable and cable lug into the side of the tee.

STEP 10: Screw the six inch long horizontal CPVC pipe into the side of the tee and screw and tighten the Woodhead cable grip into the end of the pipe.

STEP 11: Fit the cable lug over the threaded end of the rod and screw a 1/4 - 20 nut onto the rod and carefully tighten it in place.

STEP 12: Screw the pipe plug cover into the top of the CPVC tee at the top of the holder.

STEP 13: Place the new cathode or reference electrode into the electroless nickel plating tank. Connect the cathode cable to the battery type, quick disconnect connector at the bottom of the controller enclosure, or the AMP shell connector on the reference signal cable to the receptacle on the bottom of the controller enclosure.

Replacing the Program Module

Occasionally, it may be necessary to replace the controller's operating program to upgrade the unit or to install custom programming. Use the following procedure to replace the Program EPROM integrated circuit (IC) device. The IC is located on the lower left side of the power supply module circuit board as shown in the Power Supply Module Layout drawing.

STEP 1: Turn off the power to the controller and open the controller enclosure.

STEP 2: Using a small flat tool or your fingers, carefully remove the old Program Module from the circuit board. Gently pry the module up at one end and then at the other until the module pops out.

STEP 3: Using only fingers, carefully insert the new Program Module into the CPU circuit board. Be sure to note the location of Pin 1. This will correctly match the IC's pins with those in its holder.

STEP 4: Changing the EPROM will erase all of the user programmed preferences from the operating program. The set points and alarm limits must be reinstalled as described in **Section IV.**

Section XII
Warranty

Equipment manufactured by Palm Technology is warranted against defects in workmanship or materials for a period of 12 months. Equipment supplied by Palm, but manufactured by others, is covered according to the warranty furnished by their manufacturer. Palm Technology disclaims any responsibility for misuse, misapplication, negligence or improper installation of equipment. Palm Technology makes no warranty or representation regarding the fitness for use or the application of its instruments by the purchaser.

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