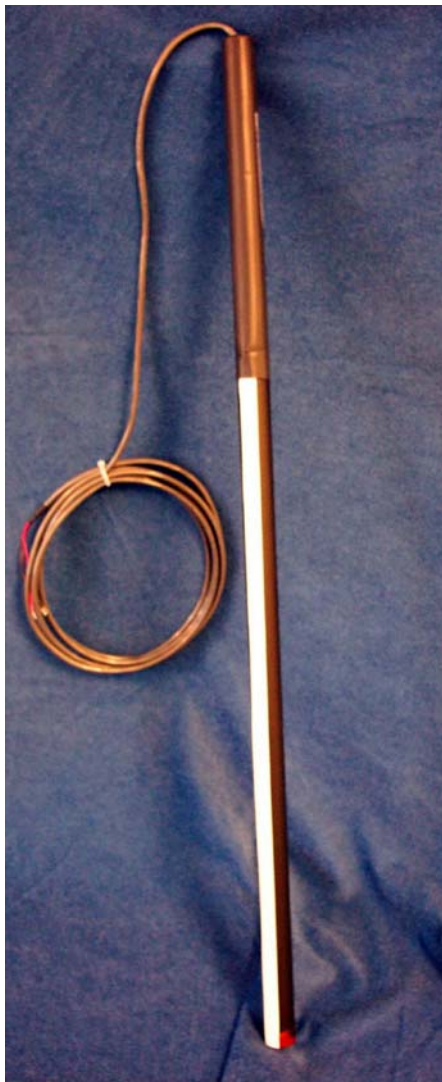




AQUA-TEL TDR TDR+T AND METER INSTALLATION MANUAL



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I. INTRODUCTION

AQUA-TEL-TDR soil moisture sensors are compatible with Automata's DATA \Rightarrow LYNX[®] telemetry system and other brands of meters, loggers and telemetry equipment. AQUA-TEL-TDR soil moisture sensors, as well as other desired sensor readings, are read at the monitoring site and transmitted through DATA \Rightarrow LYNX[®] telemetry equipment to your office computer. At the office computer, the readings are accumulated so that you can have real-time data on which to base decisions such as irrigation scheduling. For instance, if a dry soil is being indicated, a warning can automatically sound at the computer site to alert personnel that it may be time to begin irrigation. Automatic controls can start and stop pumps or open and close valves, and so forth. It's that simple! Moreover, with some additional sensors, it is possible to compute Evapotranspiration (ET) as well as Crop Water Stress Index (CWSI). These three irrigation-scheduling techniques (ET, CWSI, and soil moisture) can be compared to provide maximum assurance that the crop is managed properly.

II. GENERAL DESCRIPTION

The AQUA-TEL-TDR soil moisture sensor is an affordable and easy way to use sensor that fits a variety of applications. In computerized systems the readings from an AQUA-TEL-TDR can be used to automatically adjust irrigation schedules. Alternatively, when used in conjunction with our AQUA-TEL-TDR Meter, readings can be taken manually as often as desired. Either way, reliable soil moisture readings enable the careful manager to apply the right amount of water at the right time for optimum growing conditions.

AQUA-TEL-TDR is available in a 27.5" overall sensor length (19" active segment) and is suitable for turf, field crops and orchards. The AQUA-TEL-TDR can be ordered with a soil temperature sensor. (Model AQUA-TEL-TDR+T)

2.1 HOW THE TDR WORKS

Water is the primary factor in determining the dielectric constant of soil. The AQUA-TEL-TDR sensor measures the dielectric constant of the soil that is directly related to water content in reasonable growing conditions. Conductivity due to salinity or fertilizer applications does have a reasonable influence on AQUA-TEL-TDR measurements in the ranges that most plants tolerate.

Readings from the AQUA-TEL-TDR represent the average soil moisture over the length of the 19" active segment. The ability to average the moisture reading over the length of the sensor is a great advantage over other sensors that monitor one small point. Larger samples are more representative of the global situation.

III. SPECIFICATIONS

Specifications	
Power Requirements	12 VDC \pm 10% @ 40 mA
Output	0-1 mA. Note: This can be converted to voltage by a shunting resistor (brown wire to black wire)
Overall Size	$\frac{3}{4}$ " diameter x 27" long
Shipping Weight	1 lb.
Temperature Output	1 μ A/ $^{\circ}$ K (i.e. 0 $^{\circ}$ C = 273 μ A, 50 $^{\circ}$ C=323 μ A)
Turn on Time	1 second from power up
Options	Soil temperature included on the same probe: (Model AQUA-TEL-TDR+T). 4-20 mA output. 0-5V output.

IV. CONSIDERATIONS BEFORE INSTALLATION

Before installation can begin, consider the following:

- Location of Sensors
- Quantity of Sensors

4.1 LOCATION

We are often asked how many AQUA-TEL-TDRs should be used for various sizes of fields or types of crops. There is no single answer. Irrigation scheduling depends to some extent on soil characteristics that can vary in different parts of the same field. If your field has two or three definable areas that require different treatment because of soil structure, you should consider monitoring these areas independently. Another consideration is in the way your irrigation system has been designed to operate. If you can control your irrigations by zone, it would be advantageous to monitor each zone as an independent unit.

Figure 1

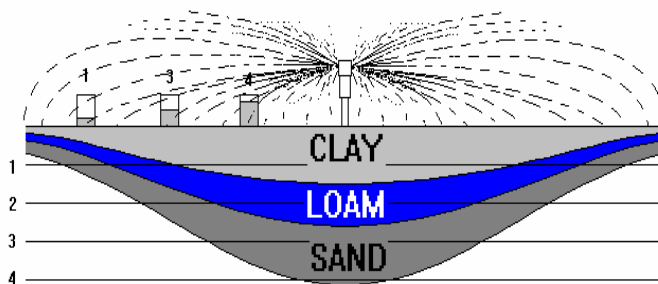
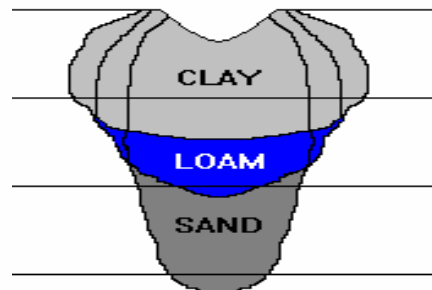


Figure 2



4.2 QUANTITY

It is common practice to use at least two soil moisture sensors at any one location in order to be able to monitor soil moisture at two levels. This is very useful in orchards and vineyards where plants are very deep rooted. In more shallow rooted crops, however, you may be able to gather all the information you need from one AQUA-TEL-TDR. Since the AQUA-TEL-TDR averages its reading over the length of the sensor and can be installed on a slant, it can monitor the entire root zone of shallow rooted plants.

Be aware of your irrigation system's distribution pattern in determining a location for the AQUA-TEL-TDR. Refer to Figure 1, which shows the penetration patterns of sprinkler and Figure 2 furrow irrigation in various soil types.

V. INSTALLATION OF THE AQUA-TEL TDR

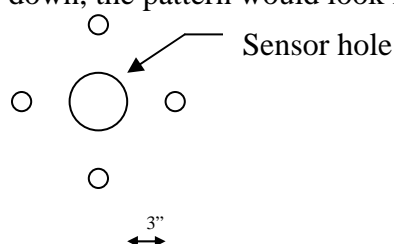
Install your AQUA-TEL-TDR sensors as early in the season as practical or leave permanently installed if possible. Location, orientation, and compaction are important factors in the installation process. Convenience is another factor, especially if the data is taken manually. Remote monitoring systems can make data collection easy and automatic, and can actually increase the usefulness of the data in many ways.

If your soil moisture sensor includes the soil temperature option (Model AQUA-TEL-TDR+T) be sure to bury the upper chassis end of the AQUA-TEL-TDR also. The temperature sensor is encased in the epoxy near the end where the cable is attached. The temperature reading is independent of the soil moisture reading and requires a separate input channel when used with a Field Station or Field Controller.

5.1 VERTICAL, SLANT OR HORIZONTAL INSTALLATION

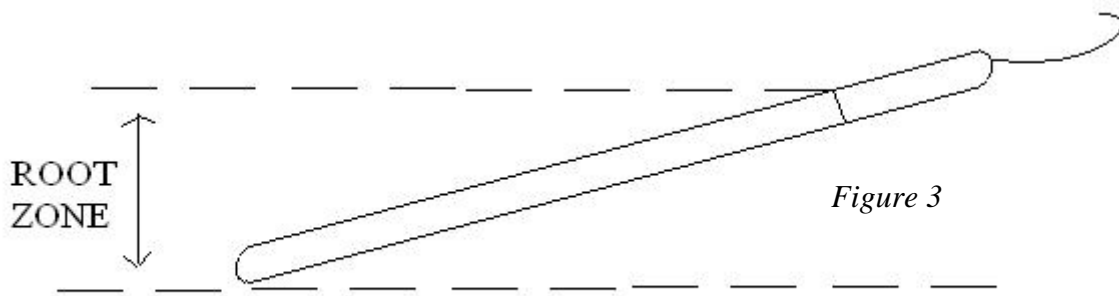
The AQUA-TEL-TDR can be installed in any orientation that suits your particular needs. AQUA-TEL-TDR soil moisture sensor measures a 19" section of soil. The first 8.5" at the end closest to the cable and the bottom 1/2" are not included in the measuring area. The sensing area must be in contact with the soil and can be placed in any direction or depth. Vertical installations produce a 19" vertical average whereas horizontal averages measure a cross section at a single depth. In deep-rooted crops, they are generally installed vertically at two or three depths.

5.1.1 Vertical Installation - A vertical shallow installation, near the surface, is often more convenient. Make a 3/4" hole just deep enough to allow the sensor to drop down to the desired measuring range. It is convenient to use a 3/4" soil sampler (can be found at an irrigation supply shop) to make the hole. **The sensor must be in intimate contact with the soil.** To make sure the soil is packed around the sensor; drive a rod about 1/2" in diameter into the ground about 3" away from the sensor, to the same depth as the sensor. Be sure the rod goes in parallel to the sensor to avoid hitting and breaking the sensor. Remove the rod and drive it down 3" away from the opposite side of the sensor. Then repeat the procedure at 90 degrees to the first set of 2 holes. Looking down, the pattern would look like this:



Pack dirt over the top to prevent water from preferentially entering the top. At deeper levels, this installation can be difficult. However, a more convenient method for deeper installations involves drilling a 2" hole in the selected location, drop the sensor in, back fill and pack the soil. Packing the soil with a pipe slightly larger diameter than the sensor.

5.1.2 Slant Installation - If you want to monitor a zone, bury it on a slant as illustrated in Figure 3. The important aspect is to ensure that the entire length of the sensing elements is covered with soil. An alternate method of packing the soil against the sensor is to prepare slurry from the native soil and fill the hole. Then insert the sensor. The slurry will help fill the space between the sensor and the soil. Slurry will often take a long time to dry and allow the sensor to give accurate ratings.



5.1.3 Horizontal Installation - Horizontal sensors are to be installed in a trench and then back filled and packed.

Note: *Disturbing the minimum amount of soil when installing the sensor reduces the stabilization time after installing the sensor.*

CAUTION: *DO NOT leave sensor lying out in the direct sun at any time.*

VI. WIRING

Each MINI, as an option of having 4 digital and/or 4 control outputs. Connectors for the analog and digital sensor and control outputs are shown in *Figure 4*. For details on where and how to hook your sensors, please refer to the WIRE INSTALLATION TABLE on the backside of the MINI spec sheet.

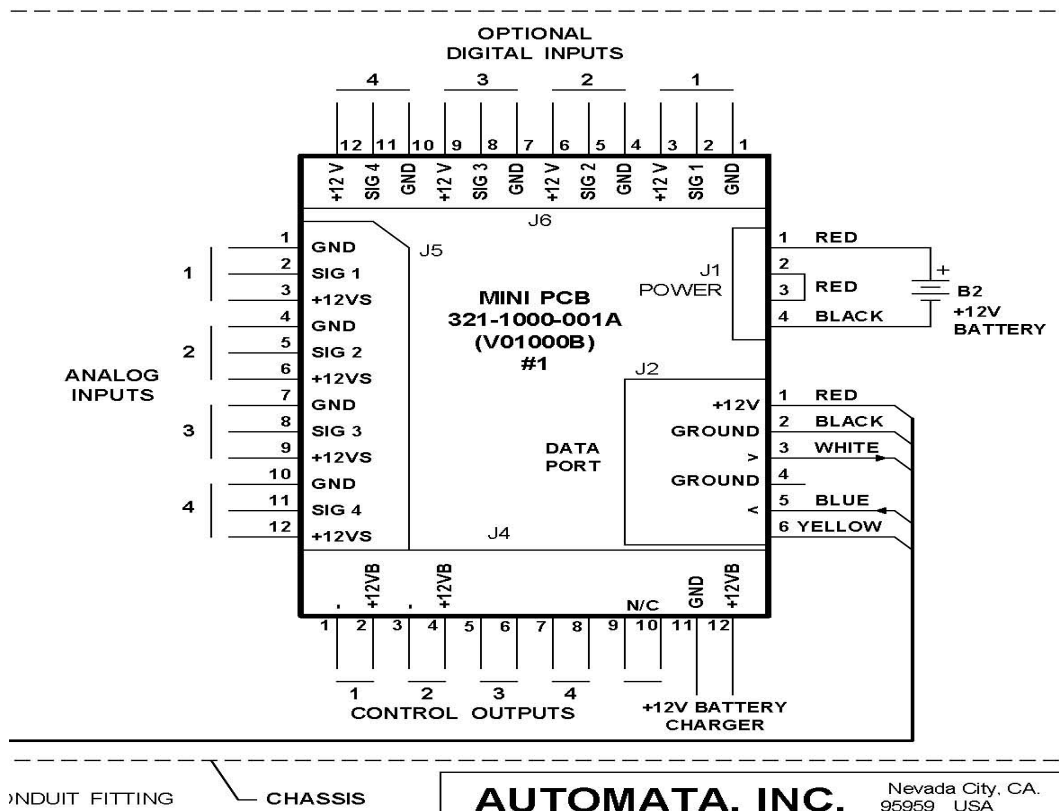


Figure 4

The standard output signal is 0-1mA, but this can be converted to a voltage output by connecting a resistor between the brown signal wire and ground. If a 5 kohm resistor is used, the output signal is 0-5 volts. A 4-20mA output version is available by special order (no extra cost). The standard AQUA-TEL-TDR cable length is 10'. Additional cable can be ordered so that no splicing is needed. The wires from the AQUA-TEL-TDR can be extended up to about 1000'; however, wire maintenance can be a problem if extremely long runs are required, and can increase the possibility of damage from lightning.

VII. START-UP

7.1 HOW TO USE THE AQUA-TEL-TDR READINGS

There are three common approaches to using the information that your AQUA-TEL-TDR provides.

1. The first is to use your expertise to determine the ideal moisture content for optimum growing conditions and use the AQUA-TEL-TDR as a reference to maintain that desired level. One should always apply all information available, such as soil samples and visual inspection in determining the optimum reading to maintain.
2. The second approach is to find the field capacity and perhaps the wilting point of each soil type by laboratory analysis. Next, calibrate the AQUA-TEL-TDR to each soil type so the absolute moisture content is known. Then use the sensor readings to maintain the moisture content in the desired range normally a little below field capacity.
3. The third practical approach in utilizing soil moisture data for irrigation is to monitor the trend. There are many factors that influence the absolute reading of soil moisture, but trends are much more reliable. Automated data acquisition is required for this approach. Field capacity is determined by watching for the "knee" in a dry down curve from saturation. (refer to figure 5)

Station Graph

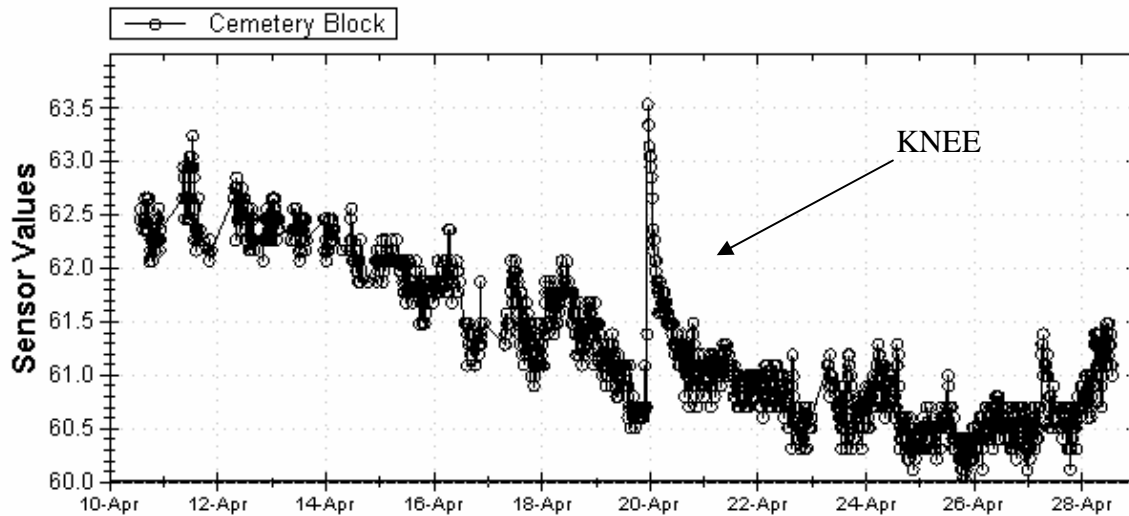


Figure 5

After the soil is saturated, the moisture level drops quickly to field capacity (knee) then the slope reduces to the plant utilization rate. Field capacity is the upper limit irrigators try to identify and is usually exceeded only for specific reasons such as leaching salts. The slope indicating plant water utilization continues thereafter, but when the water content is reduced enough (such as in deficit irrigation) eventually the slope will begin to flatten out. (refer to figure 6). Fewer slopes occur when the plants encounter difficulty in removing water from the soil.

Station Graph

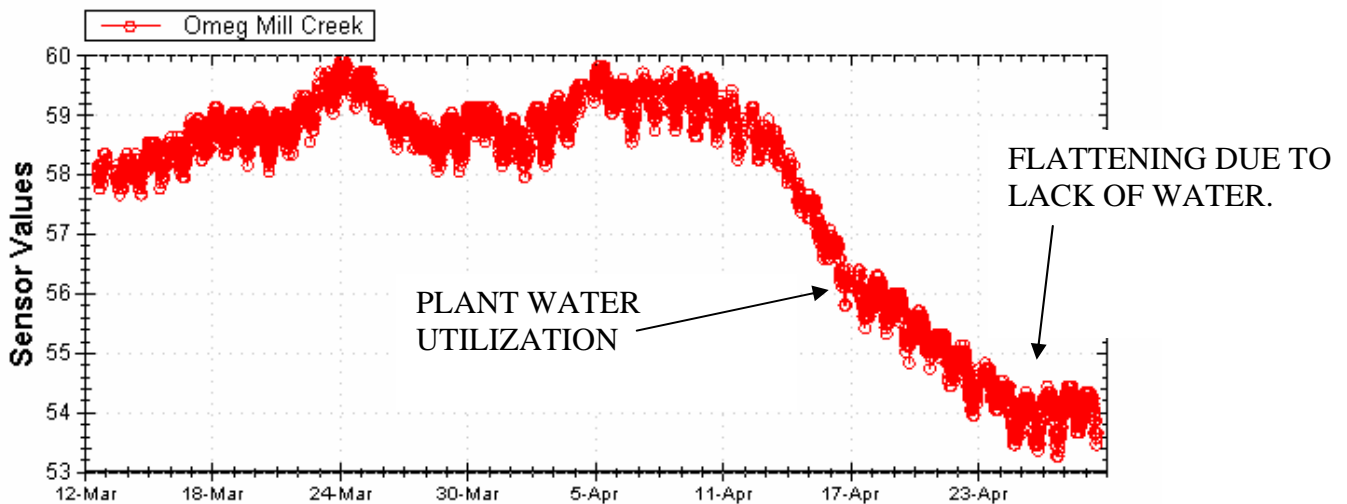


Figure 6

Additional information can be derived from probes at multiple depths, infiltration problems for example. Each measurement reflects only one location in the field. One must try to pick representative locations and/or monitor enough locations to get a valid representative sample. Analyzing the trends is best done after the soil has stabilized.

7.2 DETERMINING THE "IDEAL" SOIL MOISTURE CONTENT

Determining the ideal moisture content for a given situation requires you to know a good deal about your soil conditions and the type of plants you are raising. Historical information, soil sample analysis, ET, and careful monitoring of the health of the crop are tools to use in deciding what moisture level is best, in addition to soil moisture. Trending is the simplest method of utilizing soil moisture information. Identifying field capacity is the major factor in avoiding the waste of water and fertilizer.

Use your AQUA-TEL-TDR readings to maintain a relatively constant soil moisture level throughout the growing season.

If you will be taking readings manually (Meter or Logger), establish a regular schedule for checking and recording the readings. If you are collecting data in real-time through a computer using telemetry, get in the habit of looking at the data frequently, probably the easiest way to analyze your data is to print a graph covering several days' or more worth of readings.

Adjust your irrigation schedule to achieve the moisture level you think is best. Refer to the data you have collected and relate the readings to the points in time where your soil moisture was at the "ideal" level. If the readings vary sparsely then, calculate the average of the numbers you have chosen. The result is a number that can be used as a "trigger point" for scheduling your future irrigations.

7.3 ADJUSTING YOUR IRRIGATION SCHEDULE

If you have been graphing your AQUA-TEL-TDR data over a period of several irrigations, draw a line across the graph(s) at the "trigger point" you have chosen. If your irrigations are infrequent, you may find that the graph of the soil moisture falls well below your "trigger point" between irrigations. This indicates a need to make irrigations more frequently. Conversely, if the readings exceed the desired level continuously, you will be able to save water by not starting the next irrigation until the "trigger point" is reached. Adjust the duration to avoid exceeding field capacity unless special requirements exist.

Using Evapotranspiration for ballpark irrigation requirements is a good practice. Use all available information. Although soil moisture readings are more specific there is value in making a comparison to the global ET value. It could help catch instrumentation errors.

Continue to collect and analyze your AQUA-TEL-TDR data throughout the growing season and make adjustments to your schedule accordingly. Monitor the health of your plants also, and adjust your "trigger point" if you find that your first estimate was off.

It may be necessary to make seasonal adjustments to the "trigger point" to accommodate dormancy requirements or changing needs during a crop's growing season. Keep a record of any changes you make since that information will be valuable in future years.

7.4 CALCULATING THE AMOUNT OF WATER TO APPLY

After determining how much moisture your soil is already holding, you can calculate how much water to apply to increase the level to a desired goal. First, calculate the current volumetric content in inches of water then, determine your irrigation system's output in inches of water applied per hour of run time. Plug in the desired moisture content to find out how long to run your irrigation system. The formula is:

$\frac{\text{Target Moisture Level (Inches)} - \text{Current Volumetric Content (Inches)}}{\text{Water Application Rate (Inches / Hour)}}$	= Irrigation Runtime
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Note that you may need to break up the runtime into several separate applications in order to allow time for the water to percolate down to the level of the AQUA-TEL-TDR sensor and avoid Evapotranspiration. Also be aware of inequalities in the distribution of the water due to limitations that might be in the irrigation system's design.

VIII MAINTENANCE

The AQUA-TEL-TDR soil moisture sensor requires no maintenance if left in one location. It can remain in the ground even under freezing conditions. If the soil does freeze, however, the readings may drop off to a very low level until the ground thaws.

If the AQUA-TEL-TDR must be removed, inspect the cable for nicks or cuts that could allow water to get inside the jacket. Repair these with an appropriate compound, or return it to the factory for repair.

IX AQUA-TEL-TDR METER

The AQUA-TEL-TDR Meter is specifically designed for use with the AQUA-TEL-TDR and AQUA-TEL-TDR+T sensor. The standard soil moisture input is 0-1mA, but this can be special ordered to accommodate sensors that have a 4-20mA output. The soil moisture readings are expressed in percent.

The temperature input is designed for use with the Automata's temperature sensor, which has a 1 μ A/degree Kelvin output. The temperature input can be user calibrated by means of a potentiometer labeled "CAL" on the front of the meter. A switch on the front panel determines whether the readings are displayed in Fahrenheit or Celsius. In addition to the sensor inputs, the meter displays the internal battery voltage. The standard battery option is a battery holder that carries 8 AA batteries. The optional rechargeable battery consists of 2 six-volt lead-acid gel cells connected in series. When this option is ordered, a charger connector is installed, and a mating connector is spliced to either a 120 VAC or 240 VAC battery chargers (ordered separately).



X. WARRANTY

Automata, Inc. warrants that its products are free from defects in material and workmanship under normal use and service for a period of two years from date of shipment from our factory. Automata's obligations under this warranty are limited to replacing or repairing, at its option, any of the products determined to be defective. This warranty shall not apply to any equipment that has been repaired or altered, except by Automata, or which has been subjected to misuse, negligence, or accident. In no case shall Automata's liability exceed the original purchase price.

XI. RETURN/REPAIR

If it becomes necessary to return any of the equipment to the factory for service or repair, either during or after the above referenced warranty period, call Automata's Service Department at 800-994-0380 or 530-478-5882 to obtain a Return/Repair Materials Authorization (RMA).

Whenever possible, a cost estimate for the repair and the turn around time will be given with the RMA number.

For timely service/repair processing, write the Return/Repair Materials Authorization number on paperwork and the outside of the shipping carton in the lower left hand corner (as shown below).

TO: Automata, Inc.

Attn: Service Department

104 New Mohawk Road, Suite A

Nevada City, CA USA 95959

RMA#: (write in the RMA number you are assigned as stated above)

XII. DISCLAIMER

Automata, Inc. shall not be liable for any injury, loss or damage, direct or consequential arising out of the use of or the liability to use its product(s).

Dear Valued Customer:

Once again, thank you for your purchase of monitoring equipment from Automata, Inc. I personally want to assure you that you have purchased the best equipment available on the market. We at Automata take pride in our products, technical support, and customer service. If a problem should arise, please contact us so that we can be of immediate service to you. We value our customers!

Sincerely,



Lenny Feuer
President and Chief Engineer