

GENERAL

The Mast 727-3 UV absorption ozone photometer is enclosed entirely in a cabinet 28W x 15H x 57D centimeters (11 x 65 x 23 inches) and weighs 7 kilograms (15 pounds). Ozone concentration readings are digitally displayed on the front panel over the range 0.00 to 9.99 ppm and are also available at the analog output terminals on the back panel.

Sample gas is continually supplied to the sample chamber by a self-contained pump and sample handling system. The intensity of the UV beam traversing the 35.5 centimeter sample cell (11 centimeter in the high concentration model) is attenuated in proportion to the concentration of ozone in the sample as prescribed by Beer's Law. This signal is detected and electronically processed for presentation by the readout system.

A reference subsystem provides a good degree of stability by correcting for source intensity, optical path transmittance, and detector response changes. Self-zeroing and interference removal is accomplished by comparison of sample and reference readings.

SPECIFICATIONS

RANGE	0 – 9.99 PPM
AUTO CONTROL	± 5%
LOWER DETECTABLE LIMIT	.02 PPM
INCREMENTAL SENSITIVITY	.01 PPM
ACCURACY	±4% (Based on Beer's Law)
PRECISION (REPEATABILITY)	±1% or ±2nd Digit, <i>WHICHEVER IS GREATER</i>
ZERO DRIFT	NONE/DAY
SPAN DRIFT	1%/DAY
FLOW RATE	2 LPM NOMINAL
RISE TIME	1 MEASURING CYCLE
FALL TIME	1 MEASURING CYCLE
LINEARITY	1% up to 2ppm 4% at 10ppm (Based on Beer's Law)
TEMPERATURE RANGE	0C to 50C (32F to 122F)
POWER	110V, 50/60 HZ, 100 Watts (220V A.C. Available)

OUTPUT

DIGITAL	0.00 to 9.99 PPM
ANALOG	0-1VDC per 10 PPM

CABINET

BENCH MOUNT

WIDTH	28 cm (11 in)
HEIGHT	15 cm (6 in)
DEPTH	58 cm (23 in)
WEIGHT	7 kg. (25lbs)

INSTALLATION and OPERATION

Installing a 727-3 Ozone Monitor consists of making a connection to the air to be sampled, a power connection and, if desired, a recorder connection.

A sample connection should be made with 1/4 inch OD Teflon Tubing (supplied with monitor). Remove the nut on the inlet bulkhead connector and slip it over the end of the tube. Insert this into the connector marked "INLET" and tighten the nut finger tight. This connector is on the rear of the chassis; is off-white in color; and made of the material, kynar, a fluoroplastic which does not react with ozone and which is very similar to Teflon. Here the user will encounter one of the controversies regarding the measurement of ozone--the question of the use of input sample filters.

Since our analyzer is an optical instrument, particulate can cause an interference. However, since ambient particulate levels change gradually over a period of time, the referencing circuit eliminates this problem. At very high particulate levels (500 $\mu\text{g}/\text{M}^3$ we calculate an interference, after referencing, of only a few PPB if the particulate is in the sub-micron range; and no interference if it is greater than a micron. **NOTE: Cigarette smoking should be prohibited near the instrument and the inlet tube.**

In addition to being a potential interferent, particulate could accumulate in the optics to the point where insufficient light would be transmitted. This would necessitate more frequent cleaning of the optical system but would not cause long term errors in the data, again because of the referencing system.

Although it is not a typical situation, there is the possibility that the ambient air being sampled would have enough large particulate in it that some of the particulate would become lodged in the Teflon solenoid valve used in the referencing system. Under these circumstances, it would be advisable to use a particulate filter.

It has been determined that a .5 or 1.0 micron Teflon filter will not degrade the ozone concentration in an air sample if the filter is clean. But, if the dirt builds up on the filter, it will destroy some of the ozone in the sample. Therefore, if a filter is to be used, it must be changed regularly and should be held in a Teflon filterholder. Some people feel that filter maintenance may not be reliably performed and that this will put an unknown factor into the data. These people prefer to monitor without the use of a filter. If a filter is used, all calibrations should be done with the filter in line so that any effect the filter may have on the sample will be included in the span.

Sample air should be drawn through a standard glass or Teflon manifold with enough flow to ensure that the sample residence time is less than 10 seconds. The sampling system should make provision for a water drop out or some provision to ensure that water (rain) cannot enter the system. It should be placed as far as possible from any vent lines or any source that could contaminate the sample.

Since our instrument does not use any reagents, it is safe to vent it into a working area. The exhaust is actually ambient air with some ozone removed. For this reason, the exhaust should be prevented from reentering the sample system. However, when measuring high ozone concentrations from an

ozone chamber or other source, we recommend exhausting the sample outside the working area or using a charcoal filter at the outlet.

ELECTRICAL CONNECTION

The instrument is designed to operate on standard, single phase AC power, 50 to 60 hertz and 105 to 125 volts. If a DC to AC inverter is used as the power source, it should be capable of delivering 100 watts within the specified range and should have a sine wave output. Some inverters have a square wave output which will cause the instrument to malfunction.

A three-conductor power cable is supplied with the instrument. The round pin on the plug is the ground lead and is connected to the instrument chassis. To provide protection to personnel when operating the instrument on a two-wire receptacle, use a three-prong adapter plug ground such as a water pipe.

HAZARD WARNING Operating the instrument without a third wire ground is a dangerous electrical practice!!!!

RECORDER CONNECTION

If a strip chart recorder is to be used, it should be connected so that the high side of the recorder is connected to the terminal marked (+) on the rear of the instrument. The low side is connected to (-) which is chassis grounded. The nominal analog output is 1 volt per 10 PPM.

TURN ON AND CHECK OUT

Connect the instrument as previously described and turn on the power switch. The front display panel will light up a few moments after power is applied. If the instrument seems to be giving bad or irregular data, read the next section on warm-up.

WARM-UP

The instrument should be given 30 minutes to warm-up from the time it is first turned on. During this time you may notice that the displayed readings fluctuate by several PPM. This is normal and is caused by lamp and photo diode warm-up.

MACHINE REST

If the monitor will not be used to collect data for an extended period of time, turning it off will extend the life of the ozone scrubber and the UV source. To put the machine at rest, simply push the power button, so that the pilot light turns off.

THEORY OF OPERATION

The Mast Ozone Monitor operates on the principle of the absorption of ultra violet (UV) light by the ozone molecule. That is, if UV light passes through an air sample with a given path length, the light intensity will be lower if the sample contains ozone than it will be if it does not. The degree to which the light will be attenuated depends only upon the path length, the ozone concentration and the wave length of the light. The degree of light attenuation is expressed by the Beer-Lambert Law:

$$I = I_0 \exp (-xLC)$$

Where I_0 is the light intensity at the lower ozone concentration, I is the light intensity at the higher concentration, C is the concentration difference, L is the path length and x is the specific absorption coefficient of the gas being measured.

This is a very convenient phenomenon for making concentration measurements, in that the light attenuation is not affected by other substances provided they do not change from one measurement to the next. It is not affected by flow in that the measurement literally occurs with the speed of light, and it is not affected by temperature and pressure since the absorption depends only on the nature of the ozone molecule.

There are a number of possible difficulties in that the source of light must not change its intensity or wave length between the two measurements nor must the light detector change its sensitivity. If either changes, the degree of change must be known.

The following are requirements for an ozone measurement:

An air sample with a known ozone concentration.

An air sample identical to the first in its light absorbing properties except for an unknown ozone concentration.

A UV light source of known wavelength and fixed intensity.

A stable detector.

A known and fixed path length.

The value of x , the absorption coefficient at the wavelength being used.

Four subsystems make up the monitor:

- Optical
- Gas Flow
- Electronics
- Microprocessor

The optical subsystem consists of the UV source, an absorption cell, and a photodiode detector.

The sample detector is positioned at the opposite end of the absorption cell from the source, and measures attenuation due to the presence of ozone.

The gas flow subsystem includes the inlet and exhaust ports, the absorption cell, flowmeter, a solenoid actuated gas switch, a selective ozone filter and a sample pump. The switch directs the input gas first through the filter where ozone is selectively removed, then to the absorption cell. After a given time, the solenoid actuates the switch, sending the sample directly to the absorption cell. Alternately measuring the current (light level) at the sample detector with the ozone removed, and then with the ozone present, results in the ozone measurements. The electronics condition the signals, perform the appropriate timing functions, perform all of the arithmetic operations necessary to derive the concentrations in proper units, display the results in digital form, and generate an analog signal for recording purposes.

Item 1. in our list of requirements is just the sample air with ozone removed (the known concentration = zero). The ozone filter or scrubber is a manganese dioxide (MnO_2) filter large enough to avoid flow restriction. The MnO_2 is a very good catalyst for the reaction $\text{O}_3 \rightarrow \text{O}_2$ which means that ozone will be selectively removed from the sample. Thus, the first two items on the requirement list are provided.

The UV source is a low pressure cold cathode mercury vapor lamp with 92% of its output concentrated in the 253.7 nm emission line. Absorption by ozone is very near its maximum at this point. Emissions from the lamp shorter than this wavelength are eliminated by a vycor sheath which is put over the lamp. The vycor filter prevents the generation of ozone by the source. The 253.7 nm line is very narrow and fixed in wavelength. Thus, it is a very good source for the purposes of this instrument.

The detectors are "solar blind" cesium telluride vacuum diodes with a passband centered near 253.7 nm. The total combined optical selectivity of the detectors and lamp taken together is such that better than 99.5% of the system response is due to the 253.7 nm light. This means that the instrument is monochromatic.

Although neither the lamp nor the detectors are absolutely free of drift, the measurements are made in such a way that there is a continuous re-referencing. Therefore, the only instability in the system is that which occurs over the 10 second time interval needed to make the necessary measurements.

The path length is known and fixed. At this point five requirements are provided for: The absorption by ozone at the 253.7 nm line of mercury has been investigated at least five times using at least two independent means of determinant the ozone concentration. There is an argument that the value of x depends on chemical determination of ozone concentration and, therefore, the photometric method

is ultimately dependent on a chemical standard. This is not the case.

The principle method for determining the ozone concentration in these studies is manometric. That is, if the pressure of an ozone sample is measured and then measured again after the ozone has decayed back to oxygen, the resultant pressure rise gives a quantitative measure of the original ozone concentration. Applying the gas laws to the system $O_3 \rightarrow O_2$ there should be a 50% rise in pressure for the completed reaction. Starting with pure ozone, the pressure of the ozone gives the ozone concentration. Cross checking these two numbers gives a reliable, nonchemical determination of ozone concentration.

Combining the above with the use of electronics makes it possible to make continuous ozone measurements that are automatically calibrated and free of drift.

DETAILS

The photo diode in the instrument converts light to current through the photoelectric effect, and the current output is proportional to incident light (dark current is so small in this application that it can be ignored.) The photocurrent is detected by the electrometer where it is converted into a series of pulses. The pulse rate, or frequency, is proportional to input current; and the frequency signal is thus proportional to the light level.

There are two frequencies generated in this instrument for the purpose of making an ozone concentration determination. The sample frequency generated by the electrometer and the 25 KHz control frequency which is used for the measurement timer. The frequencies are run into counters where the pulses are totalized. This totalizing is actually an integration or averaging technique which is used to remove instability. Note: The totalizers are known as up/down counters. Running the totalizers in a forward direction is equivalent to addition and running in a reverse direction performs subtraction. The sample detector drives the sample counter and the control frequency drives the control counter. A complete measurement cycle (once every 10 to 20 seconds) runs as follows:

Both sample and control totalizers are set to zero and the solenoid is switched so that incoming sample air is passed through the scrubber and then to the sample cell. About five seconds are allowed to pass while the new sample gas (with ozone removed) is allowed to sweep out the previous sample. The sample light level is now read by allowing the sample counter to totalize in the forward direction. The totalizer runs until it reaches the number set by the span switches--the "span number". This is the reference light measurement which corresponds to I_0 in the Beer-Lambert Law.

At the same time the sample totalizer was running, the control totalizer was running. They start and stop together. The number which is now contained in the control counter corresponds to the total amount of time needed to make the sample reference measurement.

The solenoid valve switches again and now sample gas is brought directly into the sample cell. Wait five (5) seconds to flush and then take another measurement. This time the totalizers are run in the reverse direction and are allowed to run until the control totalizer is run down to zero. Thus, the amount of time used for the reference and sample measurements is exactly equal in both cases. If there is no ozone in the sample gas, the sample totalizer must, of necessity, have read the same

amount of light in the forward and reversed directions and will, therefore, total zero. This is the automatic zero feature of the instrument.

However, if ozone was present in the sample, the total down count in the sample totalizer will be a little less than it was in the up count because the ozone will have attenuated the light on the second measurement. This count, which is left in the totalizer is displayed on the front panel and is held there while the next measurement is being made.

Now, let's repeat the above with equations. A reference gas is passed through the sample cell resulting in a totalized number in the sample totalizer, N_s (up) From the Beer-Lambert Law,

$$I = I_0 \exp(-xLC)$$

but in the reference gas $C = 0$. Therefore,

$$I = I_0$$

Since the pulse rate of the signal coming from the electrometer is proportional to light level, it is possible to rephrase Beer's Law using the count, i.e.

$$N = N_0 \exp(-xLC)$$

On the up count, the counter is stopped at a number determined by the front panel switches. This is called the "span number", therefore:

$$N(\text{up}) = N_0 = N \text{ span}$$

On the down count we have:

$$N(\text{down}) = N_0 \exp(-xLC)$$

but down counting in the totalizer is equivalent to subtraction so the remaining count in the sample counter after the down count is :

$$\text{Count} = N(\text{up}) - N(\text{down})$$

Substituting the appropriate expressions, and recalling that the count in the sample counter is actually the front panel digital reading, results in:

$$\text{Reading} = N_0 - N_0 \exp(-xLC)$$

$$= N_{\text{span}} (1 - \exp(-xLC))$$

Remember, $\exp(x)$ can be expanded in a power series:

$$\exp(x) = 1 + x + x^2 + x^3 + \dots$$

For small values of x in the above expression, x and higher order terms can be neglected without

much error. This approximation causes less than a 1% error in our instrument for values of C less than 1 PPM. So, for these purposes:

$$\exp(-xLC) = 1 - xLC$$

Taking everything together, the result is:

$$\text{Reading} = N \text{ span } xLC$$

The reading is proportional to the ozone concentration. Further, the proportionality constant is given by the term Nspan xL. Where x is the absorption coefficient of ozone, a fixed molecular constant, L is path length, also fixed, and Nspan is an electronically fixed number. This means the instrument span is fixed and does not drift. It also means that an instrument calibration can be calculated from the known values of x and L by calculating Nspan as follows

$$N\text{span } xL = 10^6$$

in order for the instrument to read ozone concentration directly in PPM.

CALIBRATION

Among the list of primary calibration methods used to calibrate ozone measuring equipment are:

Ultra violet photometry
Modified spray-jet apparatus as described in ASTM Standard D1149,
"Accelerated Ozone Cracking of Vulcanized Rubber"
Boric acid buffered potassium iodide.

CALIBRATION PROCEDURE

It is the purpose of any calibration to determine the correlation between the unknown being measured and the data which the measurement system produces. An ideal calibration would, therefore, consist of a set of measurements with the system operating as it usually does with the exception that the unknown had been accurately predetermined.

There is no known method for doing this for ambient ozone, so the next best method is used. This consists of generating an air sample containing a known amount of ozone, but lacking some of the other components of ambient air.

Once the ozone containing sample has been produced, it should be injected into the sampling system in a manner which duplicates the actual sampling procedure. This will calibrate all components of the system. Unfortunately, not even this is always possible since many ozone generating systems cannot match the flow requirements of a typical sampling system. As a very minimum, the intake tube to the monitor, including the sample filter, should be included in the calibration.

If good quality data is to be obtained from a system, the system must first have undergone a calibration; and if quality is to become routine, so must calibration.

Perform the calibration as follows:

Before doing a calibration, all adjustments explained in the section on operation should be performed, allowing at least 30 minutes for warm-up.

Assemble an ozone source and measuring apparatus as described in ASTM D-1149 or February 8, 1979 Federal Register. This source should have sufficient flow capability to supply the system. This is indicated by excess flow at the vent. An excess flow of at least 500 cc/min will compensate for any flow changes in the system and will prevent ambient air from being drawn into the calibration air.

If a particulate filter is used with the monitor, the calibration air must flow through the filter. Ideally, the entire sampling system should be included in the calibration.

If a recorder is used, adjust the recorder span and zero.

Set the ozone generator until a reading of about 0.5 PPM is obtained on the monitor. Allow this reading to stabilize and then take the average of 10 up-dated display readings (about 10 minutes) at the same time a reading from the reference.

Adjust the span number located on the motherboard until the displayed reading is equal to the averaged readings from the reference.

Increasing the span number increases the instrument output. If the monitor is being used in an application where the ozone concentration is relatively constant, such as with an ozone chamber, set the ozone source to the value at which it will generally be run.

After making this adjustment, it is good practice to run one more calibration point. The outcome should verify that the instrument and the calibration procedure yield equivalent numbers.

MAINTENANCE

Maintenance items of the 727-3A are:

- UV lamp and optics
- Scrubber
- Pump diaphragm
- Pump head
- Particulate filters (if used)

UV LAMP AND OPTICS

The frequency number is a good indication of the condition of the UV lamp. A frequency number below 1.50 or a significant drop in the frequency number (e.g., 0.20 within a week) is a sign that the instrument is in need of attention. The frequency number indicates the amount of UV energy reaching the detector. A low frequency number means the UV lamp has weakened or dirty optics are attenuating the light.

To clean the optics tube simply turn the knurlized barrel back until the tube can be backed out far enough to remove. Pass a soft dry tissue once through the tube to clean it. Use a piece of plastic to push the tissue so as not to mar the tube coating. Reinstall by tightening the knurlized nut finger tight.

To clean the windows, remove the tube and loosen the screw between the tube holes. Back the detector block away from the tube holder block. The windows can then be removed and cleaned with a tissue. When handling the windows, take care not to leave fingerprints. Reverse procedure to replace windows.

The orientation of the lamp within the source block assembly will also affect the frequency number. When installing a lamp, lower the lamp until it rests on the bottom of the source block. Let the instrument warm up and observe the frequency number. Rotate the lamp a few degrees and again observe a few frequency cycles. Keep repeating this until a maximum is found. Marking the lamp body with an accompanying mark on the source block will make reinstalling the lamp easier.

If the frequency number is above 2.40, pull the lamp straight up a small amount and observe a few frequency cycles. Repeat this until the frequency number is between 2.00 and 2.40.

Installing a new lamp can be greatly facilitated if a frequency counter is available. Place the new lamp into the source block as described above and allow the instrument to warm up. Place the counter probe on pin 12 of U23 on the electrometer board. Slowly rotate the lamp until the maximum frequency is obtained. If the frequency is above 48 KHz, slowly pull the lamp straight up until the frequency is 48 KHz.

Should the frequency drop below 2.00 (40 KHz) and the lamp is not fully inserted into the source block, slide the lamp into the source block until the frequency does go to, but not past, 2.40 (48 KHz) or until the lamp rests on the bottom of the source block.

If the optics are clean and the frequency is below 1.50, the lamp is reaching the end of its life and

should be replaced. Fluctuation in the instrument's readings can also be due to a defective lamp.

SCRUBBER

A loss in sensitivity of the 727-3A is probably due to leaks in the sample handling system or a defective scrubber. A total lack of sensitivity is probably due to a faulty valve or pump. Replacing the scrubber is recommended every 12 months.

PUMP

The pump diaphragm should be checked at least every six months, or whenever there is reason to suspect the instrument is malfunctioning. Check the pump head at this time to make sure the check valves are operating correctly. Both the diaphragm and the valves should be cleaned, and any particulate found should be removed. Air should move through each port in only one direction. If the sampling system is functioning correctly, a definite suction will be felt when the finger is placed on the inlet port.

PARTICULATE FILTER (Optional)

The particulate filter should be replaced every 30 days. If the air is extremely dusty, the filter should be changed more often. If the instrument reads higher after installing a new filter, the time between changes should be decreased.

TROUBLESHOOTING AND REPAIR

A good deal of troubleshooting can be done on the basis of an understanding of how the monitor works. The theory of operation has been described previously. There follows a functional description:

There are three basic subsystems in the monitor. They are optical, gas flow, and electronic,

Optical:

Lamp - The UV source is a low pressure, cold cathode, mercury vapor lamp with 92% of its output concentrated at the 253.7 nm emission line, where absorption by ozone is maximized. Emission at wavelengths shorter than 200 nm is eliminated by a vycor optical filter around the light. Presence of the vycor filter prevents any emission at 185 nm, an emission line which generates ozone.

Detector - The detector is a "solar blind" cesium telluride vacuum diode with a broad passband centered near 253.7 nm. The total optical selectivity of the lamp and detector together is such that better than 99.5% of the detector current is due to 253.7 nm light.

Cell - The optical cell is a 35.5 cm chamber consisting of a kynar-coated aluminum or glass tube and a quartz window to isolate the gas physically from the lamp and detector.

Gas Flow:

Ozone Filter - The ozone filter is a plastic inline container filled with manganese dioxide (MnO_2). The presence of MnO_2 catalyzes the reaction of ozone to diatomic oxygen, and does not itself react with the sample. Thus, the sample going into the absorption cell after passing through the filter is preserved intact except for the ozone. Since the ambient air sample may contain a number of substances in addition to ozone, which to some extent will absorb 253.7 nm UV light, it is imperative that these substances be of the same concentration on the frequency and sample phases.

Gas Switch - The gas switch is a dual input-single output Teflon diaphragm valve. It is operated by a plunger actuated by a 24 VDC solenoid, which is turned on and off by a signal from the electronic subsystem timing circuitry. It is connected to the ozone filter in such a way as to perform the function of diverting the gas sample through the filter or sending it directly to the optical cell.

Pump - The pump, which pulls sample through the optical cell, is a brushless D.C. diaphragm type. The pumping section consists of a Teflon-coated synthetic rubber diaphragm, housed in a molded plastic casing directly driving the motor shaft by a connecting rod-crank assembly. Motor and crank pin bearings are double shielded ball bearings lubricated for the life of the unit. Valves are of the self-biasing fiberglass fabric reinforced synthetic rubber type. The drive motor is a 24 volt D.C. magnetically commutated type. At 24 volts, the pump is capable of 15 inches of water vacuum at 2.5 liters per minute, much more than adequate for the monitor's requirements.

Fittings and Tubing - In order to maintain sample integrity, all

fittings and tubing in contact with ozone containing sample are Teflon or kynar. Kynar is a fluoroplastic, off-white in color, with chemical properties similar to Teflon but superior in mechanical strength. All other fittings are nylon and tubing is tygon.

Several items and repair operations can be carried out successfully by the consumer's personnel. However, this instrument can be quite difficult to analyze and repair in regard to some of the fine detail of the electronics. For that reason, it is strongly encouraged and suggested that the consumer contact Nevada Capital Group, Inc. before attempting a repair of which he is not confident.

The more information communicated to the Nevada Capital staff, the better the situation can be judged. Please consider the following prior to contact:

Note all symptoms and any conditions under which they occur such as history, sampling site, time of day, temperature, last calibration, other pollutants, etc.

Note the serial number of the instrument and the operating time since the last maintenance operation.

Note any and all action consumer personnel may have pursued with regard to the current problem.

Note any adaptation consumer personnel may have made with regard to this specific instrument.

Check the solenoid valve. In many instruments this valve will make an audible click when it closes. If it does not, place fingers on the black solenoid cover. At closing, operator should feel a thump when the valve closes. In some instruments the thump occurs when the solenoid opens as well.

Repair and Replacement:

All repairs and replacement should be made with the power cord removed.

UV Lamp Replacement:

To remove the lamp, unplug the white, three-wire connector and pass it through the hole in the side of the chassis next to the lampholder. Loosen the set screw on the lamp holder and remove the lamp. To replace the lamp, reverse the procedure. Lamp adjustment was explained previously.

Scrubber Replacements:

To remove the scrubber, loosen the plastic nuts on the connecting tubes. Remove the scrubber. In replacing the scrubber, make sure the tube nuts are all the way on the tubes and the tubes are well into the connecting fittings. Tighten the nuts.

Pump Diaphragm Cleaning & Replacements:

Replace the tygon tubes from the pump. Note which tube is on which nipple. Follow the instructions below for diaphragm replacement.

Remove the four phillips head screws.

Clean the check valves of any particulates or change them.

Remove the four flat head screws.

Clean the diaphragm or change it.

Before reinstalling, clean both parts of the head (red and white parts).

Valves, contained within the pump head, should not be replaced in the field. These valves will not normally wear out, but may be damaged if solid foreign particles enter the system. A complete replacement pump head should then be installed.

Solenoid Replacement:

Remove scrubber. Remove the two screws on the underneath side of the chassis. Loosen the fitting nuts on the inlet and outlet side of the valve and disconnect the white connector and remove the solenoid. Remove the fittings from the valve. To replace the solenoid, take care that in putting the fittings back you do not turn them in all the way to the last thread. This will distort the valve body.

Packing for Shipment:

Prior to packaging, inspect the instrument to ensure that the cover and other mechanical parts are securely fastened and that the gas ports at the rear are covered.

Use the original shipping carton and packing material making sure the instrument is wrapped in heavy paper or plastic and three (3) inches of filler material surrounds it, including the top and bottom. Take precautions against mechanical damage, excessive humidity, negligent handling, etc.

The shipping carton should be appropriately labeled with "Scientific Instrument", "Fragile", "This Side Up", and "Handle with Care" warnings.

Mast/Keystone, Inc. will not assume any costs for damages incurred during shipping unless the instrument is returned in our original shipping carton and all of the above precautions are taken.

Always insure the instrument or specific parts being returned for its/their full value!

If an instrument or any of its parts is/are returned to Mast/Keystone, Inc. in other than its/their original shipping container(s), the company will return the item(s) in a new shipping carton for which the consumer will be charged.

Replacement Parts:

For those items which are subject to wearing out, it is generally advisable for the consumer to maintain his/its own stock and replace on a "as needed" or calendar basis as explained in the maintenance portion of this manual.

In most cases where repair is needed, the easiest procedure and the one which minimizes "down time" involves substitution of major subassemblies. If a monitor malfunctions electronically, replacement of the P.C. boards, one at a time, will generally pinpoint the problem to a specific board. Replacement of this board from the consumer's own stock will allow operation of the monitor while the defective board is being repaired.

Most parts are available "off the shelf" from electronic supply houses. However, if difficulty is encountered, all parts are available from this factory. When ordering replacement parts, be certain to include model number, part number and a complete description.